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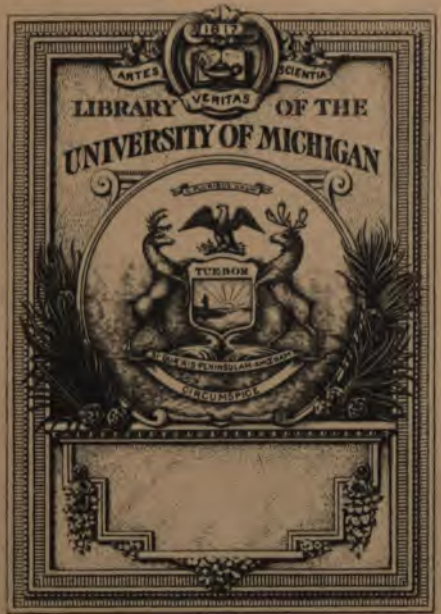


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# THE WONDERS OF LIFE

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# THE WONDERS OF LIFE

## A POPULAR STUDY OF BIOLOGICAL PHILOSOPHY

SUPPLEMENTARY VOLUME TO

*"THE RIDDLE OF THE UNIVERSE"*

BY

ERNST HAECKEL

(*Professor at Jena University*)

TRANSLATED BY JOSEPH McCABE

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# PREFACE

THE publication of the present work on *The Wonders of Life* has been occasioned by the success of *The Riddle of the Universe*, which I wrote five years ago. Within a few months of the issue of this study of the monistic philosophy, in the autumn of 1899, ten thousand copies were sold. Moreover, the publisher having been solicited on many sides to issue a popular edition of the work, more than a hundred thousand copies of this were sold within a year.[1] This extraordinary and—as far as I was concerned—unexpected success of a philosophical work which was by no means light reading, and which had no particular charm of presentation, affords ample proof of the intense interest taken by even the general reader in the object of the work—the construction of a rational and solid philosophy of life.

Naturally, the clear opposition of my monistic philosophy, based as it was on the most advanced and sound scientific knowledge, to the conventional ideas and to an outworn "revelation" led to the publication of a vast number of criticisms and attacks. During the first twelve months more than a hundred reviews and a dozen large

[1] The English translation met with almost equal success. Nearly 100,000 copies of the cheap edition have already been sold.—TRANS.

pamphlets appeared, full of the most contradictory strictures and the most curious observations. One of the ablest of my pupils, Heinrich Schmidt, gave a summary and criticism of them in his *Der Kampf um die Welträthsel*, in the autumn of 1900. However, the literary struggle went on to assume gigantic proportions when twelve different translations of the *Riddle* appeared, and led to an ever-increasing agitation in every educated country of the old and the new world.

I gave a brief reply to the chief of these attacks in April, 1903, in the appendix to the popular edition of the *Riddle*. It would be useless to go further into this controversy and meet the many attacks that have since been made. It is a question here of that profound and irreconcilable opposition between knowledge and faith, between a real knowledge of nature and an alleged "revelation," which has occupied the thoughtful and inquiring mind for thousands of years. I base my monistic philosophy exclusively on the convictions which I have gained during fifty years' close and indefatigable study of nature and its harmonious working. My dualistic opponents grant only a restricted value to these experiences; they would subordinate them to the fantastic ideas which they have reached by faith in a supernatural world of spirits. An honest and impartial consideration of this palpable contradiction discovers it to be irreconcilable—*either* science and experience, *or* faith and revelation!

For this reason I do not propose to make any further reply to the opponents of *The Riddle of the Universe*, and

I am still less disposed to take up the personal attacks which some of my critics have thought fit to make on me. In the course of this controversy I have grown painfully familiar with the means with which it is sought to silence the detested free-thinker—misrepresentation, sophistry, calumny, and denunciation. "Critical" philosophers of the modern Kantist school vie in this with orthodox theologians. What I have said in this connection of the theologian Loofs, of Halle, the philologist Dennert, of Godesberg, and the metaphysician Paulsen, of Berlin, in the appendix to the cheap German edition of the *Riddle* applies equally to many other opponents of the same type. These heated partisans may continue to attack and calumniate my person as they will; they will not hurt the sacred cause of truth in which I labour.

Much more interesting to me than these attacks were the innumerable letters which I have received from thoughtful readers of the *Riddle* during the last five years, and particularly since the appearance of a popular edition. Of these I have already received more than five thousand. At first I conscientiously replied to each of these correspondents, but I had at length to content myself with sending a printed slip with the intimation that my time and strength did not permit me to make an adequate reply. However, though this correspondence was very exacting, it afforded a very welcome proof of the lively sympathy of a large number of readers with the aim of the monistic philosophy, and a very interesting insight into the mental attitude of the most varied classes

of readers. I especially noticed that the same remarks and questions occurred in many of these five thousand letters, very often expressed in the same terms. Most of the inquiries related to biological questions, which I had cursorily and inadequately touched both in *The Riddle of the Universe* and *The History of Creation*. The natural desire to remedy these deficiencies of my earlier writings and give a general reply to my interrogators was the immediate cause of the writing of the present work on *The Wonders of Life*.

I was confirmed in this design by the circumstance that another scientist, the botanist Johannes Reinke of Kiel, had published two works in which he had treated the general problems of natural philosophy, especially of biology, from a purely dualistic and teleological point of view; these works were his *Die Welt als That* (1899) and *Einleitung in die theoretische Biologie* (1902). As both these works are well written and present the principles of dualism and teleology with admirable consistency—as far as this is possible—it seemed to me that it was desirable to give a thorough exposition of my own monistic and causative system.

Hence the present work on the wonders of life is, as the title indicates, a supplementary volume to *The Riddle of the Universe*. While the latter undertook to make a comprehensive survey of the general questions of science—as cosmological problems—in the light of the monistic philosophy, the present volume is confined to the realm of organic science, or the science of life. It seeks to deal connectedly with the general problems of

biology, in strict accord with the monistic and mechanical principles which I laid down in 1866 in my *General Morphology*. In this I laid special stress on the universality of the law of substance and the substantial unity of nature, which I have further treated in the second and fourteenth chapters of *The Riddle of the Universe*.

The arrangement of the vast material for this study of the wonders of life has been modelled on that of the *Riddle*. I have retained the division into larger and smaller sections and the synopses of the various chapters. Thus the whole biological content falls into four sections and twenty chapters. I should much have liked to add illustrations in many parts of the text to make the subject plainer, especially as regards Chapters VII., VIII., XI., and XVI.; but this would have led to a considerable increase in the size and price of the book. Moreover, there are now many illustrated works which will help the reader to go more fully into the various sections of the study. Among others, my *History of Creation* (English translation) and *Evolution of Man* (English translation now in course of preparation) will be found helpful in this way. The German reader will also find many illustrations to elucidate the text of this book in my recently completed work, *Kunstformen der Natur* (10 parts, with 100 tables, 1899–1904).

I had said, in the preface to *The Riddle of the Universe* in 1899, that I proposed to close my study of the monistic system with that work, and that "I am wholly a child of the nineteenth century, and with its close I draw the

line under my life's work." If I now seem to run counter to this observation, I beg the reader to consider that this work on the wonders of life is a *necessary* supplement to the widely-circulated *Riddle of the Universe*, and that I felt bound to write it in response to the inquiries of so many of my readers. In this second work, as in the earlier one, I make no pretension to give the reader a comprehensive statement of my monistic philosophy in the full maturity it has reached—for me personally, at least—at the close of the nineteenth century. A subjective theory of the world such as this can, naturally, never hope to have a complete objective validity. My knowledge is incomplete, like that of all other men. Hence, even in this "biological sketch-book," I can only offer studies of unequal value and incomplete workmanship. There still remains the great design of embracing all the exuberant phenomena of organic life in one general scheme and explaining all the wonders of life from the monistic point of view, as forms of one great harmoniously working universe—whether you call this Nature or Cosmos, World or God.

The twenty chapters of *The Wonders of Life* were written uninterruptedly in the course of four months which I spent at Rapallo, on the shore of the blue Mediterranean. The quiet life in this tiny coast-town of the Italian Riviera gave me leisure to weigh again all the views on organic life which I had formed by many-sided experience of life and learning since the beginning of my academic studies (1852) and my teaching at Jena

(1861). To this I was stimulated by the constant sight of the blue Mediterranean, the countless inhabitants of which had, for fifty years, afforded such ample material for my biological studies; and my solitary walks in the wild gorges of the Ligurian Apennines, and the moving spectacle of its forest-crowned mountain altars, inspired me with a feeling of the unity of living nature—a feeling that only too easily fades away in the study of detail in the laboratory. On the other hand, such a situation did not allow a comprehensive survey of the boundless literature which has been evoked by the immense advances in every branch of biology. However, the present work is not intended to be a systematic manual of general biology. In the revision of the text, on which I was engaged during the summer at Jena, I had to restrict myself to occasional additions and improvements. In this I had the assistance of my worthy pupil, Dr. Heinrich Schmidt, to whom also I am indebted for the careful revision of the proofs.

When I completed my seventieth year at Rapallo, on February 16th, I was overwhelmed with a mass of congratulations, letters, telegrams, flowers, and other gifts, most of which came from unknown readers of *The Riddle of the Universe* in all parts of the world. If my thanks have not yet reached any of them, I beg to tender them in these lines. But I should be especially gratified if they would regard this work on the wonders of life as an expression of my thanks, and as a literary gift in return. May my readers be moved by it to penetrate deeper and deeper into the glorious work of Nature, and

to reach the insight of our greatest German natural philosopher, Goethe:

> "What greater thing in life can man achieve
> Than that God-Nature be revealed to him?"

ERNST HAECKEL.

*Jena, June 17th, 1904.*

## Chapter I.

# TRUTH

Truth and the riddle of the universe. Experience and thought. Empiricism and speculation. Natural philosophy. Science. Empirical science. Descriptive science. Observation and experiment. History and tradition. Philosophic science. Theory of knowledge. Knowledge and the brain. Æstheta and phroneta. Seat of the soul, or organ of thought: phronema. Anatomy, physiology, ontogeny, and phylogeny of the phronema. Psychological metamorphoses. Evolution of consciousness. Monistic and dualistic theories of knowledge. Divergence of the two ways of attaining the truth.

What is truth? This great question has occupied the more thoughtful of men for thousands of years, and elicited myriads of attempts to answer it, myriads of truths and untruths. Every history of philosophy gives a longer or shorter account of these countless efforts of the advancing mind of man to attain a clear knowledge of the world and of itself. Nay, even "world-wisdom" itself, or philosophy in the proper sense of the word, is nothing but a connected effort to unite the general results of man's investigation, observation, reflection, and thought, and bring them to a common focus. Without prejudice and without fear, philosophy would tear the mantle from "the veiled statue of Sais," and attain a full vision of the truth. True philosophy, taken in this sense, may proudly and justly style itself "the queen of the sciences."

When philosophy, as a search for truth in the highest sense, thus unites our isolated discoveries and seeks to

weld them into one unified system of the world, it comes at length to state certain fundamental problems, the answer to which varies according to the degree of culture and the point of view of the inquirer. These final and highest objects of scientific inquiry have been of late comprehended under the title of *The Riddle of the Universe*, and I gave this name to the work I published in 1899, which dealt with them, in order to make its aim perfectly clear. In the first chapter I dealt briefly with what have been called "the seven great cosmic problems," and in the twelfth chapter I endeavoured to show that they may all be reduced to one final "problem of substance," or one great "riddle of the universe." The general formulation of this problem is effected by blending the two chief cosmic laws—the chemical law of the constancy of matter (Lavoisier, 1789), and the physical law of the constancy of force (Robert Mayer, 1842). This monistic association of the two fundamental laws, and establishment of the unified law of substance, has met with a good deal of agreement, but also with some opposition; but the most violent attacks were directed against my monistic theory of knowledge, or against the method I followed in seeking to solve the riddle of the universe. The only paths which I had recognised as profitable were those of experience and thought—or empirical knowledge and speculation. I had insisted that these two methods supplemented each other, and that they alone, under the direction of reason, lead to the attainment of truth. At the same time I had rejected as false two other much-frequented paths which purported to lead directly to a profounder knowledge, the ways of emotion and revelation; both of these are in opposition to reason, since they demand a belief in miracles.

"All natural science is philosophy, and all true philosophy is natural science. All true science is natural philosophy." I expressed in these words the general result of my monistic studies in 1866 (in the 27th chapter of my *Generelle Morphologie*). I then laid it down as the fundamental principle of the monistic system that the unity of nature and the unity of science follow absolutely from any connected study of modern philosophic science, and I expressed my conviction in these terms: "All human science is knowledge based on experience, or empirical philosophy; or, if the title be preferred, philosophic empiricism. Thoughtful experience, or thought based on experience, is the only way and method to be followed in the search for truth." I endeavoured to establish these theses conclusively in the first book of the *Generelle Morphologie*, which contains (p. 108) a critical and methodological introduction to this science. Not only are those methods considered "which must necessarily supplement each other" (I. Empiricism and Philosophy; II. Analysis and Synthesis; III. Induction and Deduction), but also those "which necessarily exclude each other" (IV. Dogmatism and Criticism; V. Teleology and Causality, or Vitalism and Mechanicism; VI. Dualism and Monism). The monistic principles which I developed there thirty-eight years ago have only been confirmed by my subsequent labours, and so I may refer the interested reader to that work. *The Riddle of the Universe* is in the main an attempt to introduce to the general reader in a convenient form the chief points of the monistic system I established. However, the opposition which has been aroused by the general philosophic observations of the *Riddle* compels me to give a further explanation of the chief features of my theory of knowledge.

All true science that deserves the name is based on a collection of experiences, and consists of conclusions that have been reached by a rational connection of these experiences. "Only in experience is there truth," says Kant. The external world is the object that acts on man's organs of sense, and in the internal sense-centres of the cortex of the brain these impressions are subjectively transformed into presentations. The thought-centres, or association centres, of the cortex (whether or no one distinguishes them from the sense-centres) are the real organs of the mind that unite these presentations into conclusions. The two methods of forming these conclusions —induction and deduction, the formation of arguments and concepts, thought and consciousness—make up together the cerebral function we call reason. These long familiar and fundamental truths, the recognition of which I have described for thirty-eight years as the first condition for solving the riddle of life, are still far from being generally appreciated. On the contrary, we find them combated by the extreme representatives of both tendencies of science. On the one side, the empirical and descriptive school would reduce the whole task to experience, without calling in the aid of philosophy; while philosophic speculation, on the other side, would dispense with experience and endeavour to construct the world by pure thought.

Starting from the correct principle that all science originally has its source in experience, the representatives of "experimental science" affirm that their task consists solely in the exact observation of "facts" and the classification and description of them, and that philosophic speculation is nothing more than an idle play of ideas. Hence this one-sided sensualism, as Condillac and Hume especially maintained it, affirmed

that the whole action of the mind consists in a manipulation of sense-impressions. This narrow empirical conception spread very widely during the nineteenth century, particularly in the second half, among the rapidly-advancing sciences; it was favoured by the specialism which grew up in the necessary division of labour. The majority of scientists are still of opinion that their task is confined to the exact observation and description of facts. All that goes beyond this, and especially all far-reaching philosophic conclusions from their accumulated observations, are regarded by them with suspicion. Rudolph Virchow strongly emphasised this narrow empirical tendency ten years ago. In his speech on the foundation of the Berlin University he explained the "transition from the philosophic to the scientific age"; he said that the sole aim of science is "the knowledge of facts, the objective investigation of natural phenomena in detail." The former politician seemed to forget that he had maintained a precisely opposite view forty years before (at Würtzburg), and that his own great achievement, the creation of cellular pathology, was a philosophic construction—the formation of a new and comprehensive theory of disease by the combination of countless observations and the conclusions deduced therefrom.

No science of any kind whatever consists solely in the description of observed facts. Hence we can only regard it as a pitiful contradiction in terms when we find biology classed in official documents to-day as a "descriptive science," and physics opposed to it as an "explanatory science." As if in both cases we had not, after describing the observed phenomena, to pass on to trace them to their causes—that is, to *explain* them—by means of rational inferences! But it is even more regrettable

to find that one of the ablest scientists of Germany, Gustav Kirchhoff, has claimed that description is the final and the highest task of science. The famous discoverer of spectrum analysis says in his *Lectures on Mathematical Physics and Mechanics* (1877): "It is the work of science to describe the movements perceived in Nature, in the most complete and simplest fashion." There is no meaning in this statement unless we take the word "description" in a quite unusual sense—unless "complete description" is meant to include explanation. For thousands of years true science has been, not merely a simple description of individual facts, but an explanation of them by tracing them to their causes. It is true that our knowledge of them is always imperfect, or even hypothetical; but this is equally true of the description of facts. Kirchhoff's statement is in flagrant contradiction to his own great achievement, the founding of spectrum analysis; for the extraordinary significance of this does not lie in the discovery of the wonderful facts of spectroscopic optics and the "complete description" of individual spectra, but in the rational grouping and interpretation of them. The far-reaching conclusions that he has drawn from them have opened out entirely new paths to physics and chemistry. Hence Kirchhoff is in as sad a plight as Virchow when he formulates so precarious a principle. However, these statements of the two great scientists have done a great deal of harm, as they have widened still more the deep gulf between science and philosophy. It may be of some service if a few thousand of the thoughtless followers of "descriptive science" are persuaded to refrain from attempts at explanation of facts. But the master-builders of science cannot be content with the collection of dead material; they must press on to the

knowledge of causes by a rational manipulation of their facts.

The accurate and discriminating observation of facts, supported by careful experiment, is certainly a great advantage that modern science has over all earlier efforts to attain the truth. The distinguished thinkers of classic antiquity were far superior to most modern scientists and philosophers in regard to judgment and reasoning, or all the subtler processes of thought; but they were superficial and unpractised observers, and were barely acquainted with experiment. In the Middle Ages scientific work degenerated in both its aspects, as the dominant creed demanded only faith and the recognition of its supernatural revelation, and depreciated observation. The great importance of this as a foundation of real knowledge was first appreciated by Bacon of Verulam, whose *Novum Organon* (1620) laid down the principles of scientific knowledge, in opposition to the current scholasticism derived from Aristotle and his *Organon*. Bacon became the founder of modern empirical investigation, not only by making careful and exact observation of phenomena the basis of all philosophy, but also in demanding the supplementing of this by experiment; by this experiment he understood the putting of a question to Nature, as it were, which she must herself answer—a kind of observation under definite and deliberate conditions.

This more rigorous method of "exact observation," which is hardly 300 years old, was very strongly aided by the inventions which enable the human eye to penetrate into the farthest abysses of space and the profoundest depths of smaller bodies—the telescope and microscope. The great improvement in these instruments during the nineteenth century, and the support

given by other recent inventions, have led to triumphs of observation in this "century of science" that surpassed all anticipation. However, this very refinement of the technique of observation has its drawbacks, and has led to many an error. The effort to obtain the utmost accuracy in *objective* observation has often led to a neglect of the part which is played by the *subjective* mental action of the observer; his judgment and reason have been depreciated in comparison with the acuteness and clearness of his vision. Frequently the means has been turned into the end of knowledge. In the reproduction of the thing observed the objective photograph, presenting all parts of the object with equal plainness, has been more valued than the subjective design that reproduces only what is essential and leaves out what is superfluous; yet the latter is in many cases (for instance, in histological observation) much more important and correct than the former. But the greatest fault has been that many of these "exact" observers have refrained altogether from reflection and judgment on the phenomena observed, and have neglected subjective criticism; hence it is that so often a number of observers of the same phenomenon contradict each other, while each one boasts of the "exactness" of his observations.

Like observation, experimentation has been wonderfully improved of late years. The experimental sciences which make most use of it—experimental physics, chemistry, physiology, pathology, etc.—have made astounding progress. But it is just as important in the case of experiment—or observation under artificial conditions—as of simple observation that it be undertaken and carried out with a sound and clear judgment. Nature can only give a correct and unambiguous answer

to the question you put it when it is clearly and distinctly proposed. This is very often not the case, and the experimenter loses himself in meaningless efforts, with the foolish hope that "something may come of it." The modern province of experimental or mechanical embryology is especially marred by these useless and perverse experiments. Equally foolish is the conduct of those biologists who would transfer the experiment that is valuable in physiology to the field of anatomy, where it is rarely profitable. In the modern controversy about evolution the attempt is frequently made to prove or refute experimentally the origin of species. It is quite forgotten that the idea of species is only relative, and that no man of science can give an absolute definition of it. Nor is it less perverse to attempt to apply experimentation to historical problems where all the conditions for a successful application are lacking.

The knowledge which we obtain directly by observation and experiment is only sound when it refers to present events. We have to turn to other methods for the investigation of the past—to history and traditions; and these are less easily accessible. This branch of science has been investigated for thousands of years, as far as the history of man and civilisation, of peoples and States, and their customs, laws, languages, and migrations, is concerned. In this, the oral and written tradition from generation to generation, the ancient monuments, and documents, and weapons, etc., furnish an abounding empirical material from which critical judgment can draw a host of conclusions. However, the door to error lies wide open here, as the documents are usually imperfect, and the subjective interpretation of them is often no clearer than their objective validity.

Natural history, properly so called, or the study of the origin and past history of the universe, the earth, and its organic population, is much more recent than the history of mankind. Immanuel Kant was the first to lay the foundations of a mechanical cosmogony in his remarkable *Natural History of the Heavens* (1755), and Laplace gave mathematical shape to his ideas in 1796. Geology, also, or the story of the evolution of the earth, was not founded until the beginning of the eighteenth century, and did not assume a definite shape until the time of Hoff and Lyell (1830). Later still (1866) were laid the foundations of the science of organic evolution, when Darwin provided a sound foundation, in his theory of selection, for the theory of descent which Lamarck had proposed fifty years before.

In sharp contrast to this purely empirical method, which is favoured by most men of science in our day, we have the purely speculative tendency which is current among our academic philosophers. The great regard which the critical philosophy of Immanuel Kant obtained during the nineteenth century has recently been increased in the various schools of philosophy. As is known, Kant affirmed that only a part of our knowledge is empirical, or *à posteriori*—that is, derived from experience; and that the rest of our knowledge (as, for instance, mathematical axioms) is *à priori*—that is to say, reached by the deductions of pure reason, independently of experience. This error led to the further statement that the foundations of science are metaphysical, and that, though man can attain a certain knowledge of phenomena by the innate forms of space and time, he cannot grasp the "thing in itself" that lies behind them. The purely speculative metaphysics which was built up on Kant's apriorism, and which found its extreme representative in

Hegel, came at length to reject the empirical method altogether, and insisted that all knowledge is obtained by pure reason, independently of experience.

Kant's chief error, which proved so injurious to the whole of subsequent philosophy, lay in the absence of any physiological and phylogenetic base to his theory of knowledge; this was only provided sixty years after his death by Darwin's reform of the science of evolution, and by the discoveries of cerebral physiologists. He regarded the human mind, with its innate quality of reason, as a completely formed entity from the first, and made no inquiry into its historical development. Hence, he defended its immortality as a practical postulate, incapable of proof; he had no suspicion of the evolution of man's soul from that of the nearest related mammals. The curious predisposition to *à priori* knowledge is really the effect of the inheritance of certain structures of the brain, which have been formed in man's vertebrate ancestors slowly and gradually, by adaptation to an association of experiences, and therefore of *à posteriori* knowledge. Even the absolutely certain truths of mathematics and physics, which Kant described as synthetic judgments *à priori*, were originally attained by the phyletic development of the judgment, and may be reduced to constantly repeated experiences and *à priori* conclusions derived therefrom. The "necessity" which Kant considered to be a special feature of these *à priori* propositions would be found in all other judgments if we were fully acquainted with the phenomena and their conditions.

Among the censures which the academic metaphysicians, especially in Germany, have passed on my *Riddle of the Universe*, the heaviest is perhaps the charge that I know nothing whatever about the theory of knowledge. The

charge is correct to this extent, that I do *not* understand the current dualistic theory of knowledge which is based on Kant's metaphysics; I cannot understand how their introspective psychological methods—disdaining all physiological, histological, or phylogenetic foundations—can satisfy the demands of "pure reason." My monistic theory of knowledge is assuredly very different from this. It is firmly and thoroughly based on the splendid advances of modern physiology, histology, and phylogeny—on the remarkable results of these empirical sciences in the last forty years, which are entirely ignored by the prevailing system of metaphysics. It is on the ground of these experiences that I have adopted the views on the nature of the human mind which are expounded in the second part of *The Riddle of the Universe* (chaps. vi.–xi.). The following are the chief points:—

1. The soul of man is—objectively considered—essentially similar to that of all other vertebrates; it is the physiological action or function of the brain.

2. Like the functions of all other organs, those of the brain are effected by the cells, which make up the organ.

3. These brain-cells, which are also known as soul-cells, ganglionic cells, or neurona, are real nucleated cells of a very elaborate structure.

4. The arrangement and grouping of these psychic cells, the number of which runs into millions in the brain of man and the other mammals, is strictly regulated by law, and is distinguished within this highest class of the vertebrates by several characteristics, which can only be explained by the common origin of the mammals from one primitive mammal (or pro-mammal of the Triassic period).

5. Those groups of psychic cells which we must regard as the agents of the higher mental functions have their

origin in the fore-brain, the earliest and foremost of the five embryonic brain-vesicles; they are confined to that part of the surface of the fore-brain which anatomists call the cortex, or gray bed, of the brain.

6. Within the cortex we have localised a number of different mental activities, or traced them to certain regions; if the latter are destroyed, their functions are extinguished.

7. These regions are so distributed in the cortex that one part of them is directly connected with the organs of sense, and receives and elaborates the impressions from these: these are the inner sense-centres, or sensoria.

8. Between these central organs of sense lie the intellectual or thought-organs, the instruments of presentation and thought, judgment and consciousness, intellect and reason; they are called the thought-centres, or association-centres, because the various impressions received from the sense-centres are associated, combined, and united in harmonious thought by them.[1]

The anatomic distinction between the two regions of the cortex which we oppose to each other as the internal sense-centres and the thought or association-centres seems to me of the highest importance. Certain physiological considerations had for some time suggested this distinction, but the sound anatomic proof of it has only been furnished during the last ten years. In 1894 Flechsig showed that there are four central sense-regions ("internal sense-spheres" or æstheta) in the gray cortex of the brain, and four thought-centres ("association-centres," or phroneta) between these: the most important of the

[1] Further particulars about the relations of the thought-centres to the sense-centres will be found in the tenth chapter of *The Riddle of the Universe*.

latter, from the psychological point of view, is the "principal brain," or the "great occipito-temporal association-centre." The anatomic determination of the two "psychic regions" which Flechsig first introduced was afterwards modified by himself and substantially altered by others. The distinguished works of Edinger, Weigert, Hitzig, and others, lead to somewhat discrepant conclusions. But for the general conception of psychic action, and especially of the cognitive functions, which interests us at present, it is not necessary to have this delimitation of the regions. The chief point holds, that we can to-day anatomically distinguish between the two most important organs of mental life; that the neurona, which compose both, differ histologically (or in finer structure) and ontogenetically (or in origin); and that even chemical differences (or a different relation to certain colouring matters) may be perceived. We may conclude from this that the neurona or psychic cells which compose both organs also differ in their finer structure; there is probably a difference in the complicated fibrils which extend in the cytoplasm of both organs, although our coarse means of investigation have not yet succeeded in detecting this difference. In order to distinguish properly between the two sets of neurona, I propose to call the sensory-cells or sense-centres *æsthetal cells*, and the thought-cells or thought-centres *phronetal cells*. The former are, anatomically and physiologically, the intermediaries between the external sense-organs and the internal thought-organs.

To this anatomic delimitation of the internal sense-centres and thought-organs in the cortex corresponds their physiological differentiation. The sensorium, or sense-centre, works up the external sense-impressions that are conveyed by the peripheral sense-organs and the

specific energy of their sensory nerves; the *æstheta*, or the central sense-instruments that make up the sensorium, and their organic units, the *æsthetal cells*, prepare the sense-impressions for thought and judgment in the proper sense. This work of "pure reason" is accomplished by the *phronema* of the thought-centres, the *phroneta* (or the various thought-organs that compose it) and their histological elements, the phronetal cells, bringing about an association or combination of the prepared impressions. By this important distinction we avoid the error of the older sensualism (of Hume, Condillac, etc.)—namely, that all knowledge depends on sense-action alone. It is true that the senses are the original source of all knowledge; but, in order to have real knowledge and thought, the specific task of reason, the impressions received from the external world by the sense-organs, and their nerves and centres, must be combined in the association-centres and elaborated in the conscious thought-centres. Then there is the important, but frequently overlooked, circumstance that there is in advance in the phronetal cells of the civilised man a valuable quality in the shape of inherited potential nerve-energy, which was originally engendered by the actual sense-action of the æsthetal cells in the course of many generations.

An impartial and critical study of the action of the brain in various scientific leaders shows that, as a rule, there is a certain opposition, or an antagonistic correlation, between the two sections of the highest mental power. The empirical representatives of science, or those who are devoted to physical studies, have a preponderant development of the sensorium, which means a greater disposition and capacity for the observation of phenomena in detail. On the other hand, the speculative

representatives of what is called mental science and philosophy, or of metaphysical studies, have the phronema more strongly developed, which means a preponderant tendency to, and capacity for, a comprehensive perception of the universal in particulars. Hence it is that metaphysicians usually look with disdain on "materialistic" scientists and observers; while the latter regard the play of ideas of the former as an unscientific and speculative dissipation. This physiological antagonism may be traced histologically to the comparative development of the æsthetal and the phronetal cells in the two cases. It is only in natural philosophers of the first rank, such as Copernicus, Newton, Lamarck, Darwin, and Johannes Müller, that both sections are harmoniously developed, and thus the individual is equipped for the highest mental achievements.

If we take the ambiguous term "soul" (*psyche* or *anima*) in the narrower sense of the higher mental power, we may assign as its "seat" (or, more correctly, its organ), in man and the other mammals, that part of the cortex which contains the phroneta and is made up of the phronetal cells; a short and convenient name for this is the *phronema*. According to our monistic theory, the phronema is the organ of thought in the same sense in which we consider the eye the organ of vision, or the heart the central organ of circulation. With the destruction of the organ its function disappears. In opposition to this biological and empirically-grounded theory, the current metaphysical psychology regards the brain as the seat of the soul, only in a very different sense. It has a strictly dualistic conception of the human soul as a being apart, only dwelling in the brain (like a snail in its shell) for a time. At the death of the brain it is supposed to live on, and indeed for all eternity. The

immortal soul, on this theory (which we can trace to Plato), is an immaterial entity, feeling, thinking, and acting independently, and only using the material body as a temporary implement. The well-known "piano-theory" compares the soul to a musician who plays an interesting piece (the individual life) on the instrument of the body, and then deserts it, to live for ever on its own account. According to Descartes, who ensured the widest acceptance for Plato's dualistic mysticism, the proper habitation of the soul in the brain—in the music-room—is the pineal gland, a posterior section of the middle-brain (the second embryonic cerebral vesicle). The famous pineal gland has lately been recognised by comparative anatomists as the rudiment of a single organ of vision, the pineal eye (which is still found in certain reptiles). Moreover, not one of the innumerable psychologists who seek the seat of the soul in some part of the body, after the fashion of Plato, has yet formulated a plausible theory of the connection of mind and body and the nature of their reciprocal action. On our monistic principles the answer to this question is very simple, and consonant with experience. In view of its extreme importance, it is advisable to devote at least a few lines to the consideration of the phronema in the light of anatomy, physiology, ontogeny, and phylogeny.

When we conceive the phronema as the real "organ of the soul" in the strict sense—that is to say, as the central instrument of thought, knowledge, reason, and consciousness—we may at once lay down the principle that there is an anatomical unity of organ corresponding to the physiological and generally admitted unity of thought and consciousness. As we assign to this phronema a most elaborate anatomical structure, we may call it the organic apparatus of the soul, in the

same sense in which we conceive the eye as a purposively arranged apparatus of vision. It is true that we have as yet only made a beginning of the finer anatomic analysis of the phronema, and are not yet able to mark off its field decisively from the neighbouring spheres of sense and motion. With the most improved means of modern histology, the most perfect microscopes and colouring methods, we are only just beginning to penetrate into the marvellous structure of the phronetal cells and their complicated grouping. Yet we have advanced far enough to regard it as the most perfect piece of cell-machinery and the highest product of organic evolution. Millions of highly differentiated phronetal cells form the several stations of this telegraphic system, and thousands of millions of the finest nerve-fibrils represent the wires which connect the stations with each other and with the sense-centres on the one hand, and with the motor-centres on the other. Comparative anatomy, moreover, acquaints us with the long and gradual development which the phronema has undergone within the higher class of the vertebrates, from the amphibia and reptiles up to the birds and mammals, and, within the last class, from the monotremes and marsupials up to the apes and men. The human brain seems to us to-day to be the greatest marvel that plasm, or the "living substance," has produced in the course of millions of years.

The remarkable progress which has been made in the last few decades in the anatomic and histological investigation of the brain does not yet, it is true, enable us to make a clear delimitation of the region of the phronema and its relations to the neighbouring sensory and motor spheres in the cortex. We must, in fact, assume that there is no sharp distinction in the lower stages of the

vertebrate soul; in the older and phylogenetically more distant stages they were not yet differentiated. Even now there are still intermediaries between the æsthetal and phronetal cells. But we may expect with confidence that further progress in the comparative anatomy of the brain will, with the aid of embryology, throw more and more light on these complicated structures. In any case, the fundamental fact is now empirically established that the phronema (the real organ of the soul) forms a definite part of the cortex of the brain, and that without it there can be no reason, no mental life, no thought, and no knowledge.

Since we regard psychology as a branch of physiology, and examine the whole of the phenomena of mental life from the same monistic standpoint as all other vital functions, it follows that we can make no exception for knowledge and reason. In this we are diametrically opposed to the current systems of psychology, which regard psychology, not as a natural science, but as a mental science. In the next chapter we shall see that this position is wholly unjustified. Unfortunately, this dualistic attitude is shared by a number of distinguished modern physiologists, who otherwise adopt the monistic principles; they take the soul to be, in the Cartesian sense, a supernatural entity. Descartes—a pupil of the Jesuits—only applied his theory to man, and regarded animals as soulless automata. But the theory is quite absurd in modern physiologists, who know from innumerable observations and experiments that the brain, or psychic organ, in man behaves just as it does in the other mammals, and especially the primates. This paradoxical dualism of some of our modern physiologists may be partly explained by the perverse theory of knowledge which the great authority of Kant, Hegel, etc., has

imposed on them; and partly by a concern for the current belief in immortality, and the dread of being decried as "Materialists" if they abandon it. As I do not share this belief, I examine and appreciate the physiological work of the phroneta just as impartially as I deal with the organs of sense or the muscles. I find that the one is just as much subject as the other to the law of substance. Hence we must regard the chemical processes in the ganglionic cells of the cortex as the real factors of knowledge and all other psychic action. The chemistry of the neuroplasm determines the vital function of the phronema. The same must be said of its most perfect and enigmatic function, consciousness. Although this greatest wonder of life is only directly accessible by the introspective method, or by the mirroring of knowledge in knowledge, nevertheless the use of the comparative method in psychology leads us to believe confidently that the lofty self-consciousness of man differs only in degree, and not in kind, from that of the ape, dog, horse, and other higher mammals.

Our monistic conception of the nature and seat of the soul is strongly confirmed by psychiatry, or the science of mental disease. As an old medical maxim runs, *Pathologia physiologiam illustrat*—the science of disease throws light on the sound organism. This maxim is especially applicable to mental diseases, for they can all be traced to modifications of parts of the brain which discharge definite functions in the normal state. The localisation of the disease in a definite part of the phronema diminishes or extinguishes the normal mental function which is discharged by this section. Thus disease of the speech-centre, in the third frontal convolution, destroys the power of speech; the destruction of the visual region (in the occipital convolutions) does away

with the power of sight; the lesion of the temporal convolutions destroys hearing. Nature herself here conducts delicate experiments which the physiologist could only accomplish very imperfectly or not at all. And although we have in this way only succeeded as yet in showing the functional dependence of a certain part of the mental functions on the respective parts of the cerebrum, no unprejudiced physician doubts to-day that it is equally true of the other parts. Each special mental activity is determined by the normal constitution of the relevant part of the brain, a section of the phronema. Very striking examples of this are afforded in the case of idiots and microcephali, the unfortunate beings whose cerebrum is more or less stunted, and who have accordingly to remain throughout life at a low stage of mental capacity. These poor creatures would be in a very pitiable condition if they had a clear consciousness of it, but that is not the case. They are like vertebrates from which the cerebrum has been partly or wholly removed in the laboratory. These may live for a long time, be artificially fed, and execute automatic or reflex (and in part purposive) motions, without our perceiving a trace of consciousness, reason, or other mental function in them.

The embryology of the child-soul has been known in a general way for thousands of years, and has been an object of keen interest to all observant parents and teachers; but it was not until about twenty years ago that a strictly scientific study was made of this remarkable and important phenomenon. In 1884 Kussmaul published his *Untersuchungen über das Seelenleben des neugeborenen Menschen*, and in 1882 W. Preyer published his *Mind of the Child* [English translation; Dr. J. Sully has several works on the same subject]. From the careful manuals which these and other observers have published,

it is clear that the new-born infant not only has no reason or consciousness, but is also deaf, and only gradually developes its sense and thought-centres. It is only by gradual contact with the outer world that these functions successively appear, such as speech, laughing, etc.; later still come the power of association, the forming of concepts and words, etc. Recent anatomic observations quite accord with these physiological facts. Taken together, they convince us that the phronema is undeveloped in the new-born infant; and so we can no more speak in this case of a "seat of the soul" than of a "human spirit" as a centre of thought, knowledge, and consciousness. Hence the destruction of abnormal new-born infants—as the Spartans practised it, for instance, in selecting the bravest—cannot rationally be classed as "murder," as is done in even modern legal works. We ought rather to look upon it as a practice of advantage both to the infants destroyed and to the community. As the whole course of embryology is, according to our biogenetic law, an abbreviated repetition of the history of the race, we must say the same of psychogenesis, or the development of the "soul" and its organ—the phronema.

Comparative psychology comes next in importance to embryology as a means of studying the ancestral history of the soul. Within the ranks of the vertebrates we find to-day a long series of evolutionary stages which reach up from the lowest acrania and cyclostoma to the fishes and dipneusta, from these to the amphibia, and from these again to the amniota. Among the latter, moreover, the various orders of reptiles and birds on the one hand, and of mammals on the other, show us how the higher psychic powers have been developed step by step from the lower. To this physiological

scale corresponds exactly the morphological gradation revealed by the comparative anatomy of the brain. The most interesting and important part of this is that which relates to the highest developed class—the mammals; within this class we find the same ever-advancing gradation. At its summit are the primates (man, the apes, and the half-apes), then the carnivora, a part of the ungulates, and the other placentals. A wide interval seems to separate these intelligent mammals from the lower placentals, the marsupials and monotremes. We do not find in the latter the high quantitative and qualitative development of the phronema which we have in the former; yet we find every intermediate stage between the two. The gradual development of the cerebrum and its chief part—the phronema—took place during the Tertiary period, the duration of which is estimated by many recent geologists at from twelve to fifteen (at the least three to five) million years.

As I have gone somewhat fully, in chapters vi.–ix. of the *Riddle*, into the chief results of the modern study of the brain and its radical importance for psychology and the theory of knowledge, I need only refer the reader thereto. There is just one point I may touch here, as it has been attacked with particular vehemence by my critics. I had made several allusions to the works of the distinguished English zoologist, Romanes, who had made a careful comparative study of mental development in the animal and man, and had continued the work of Darwin. Romanes partly retracted his monistic convictions shortly before his death, and adopted mystic religious views. As this conversion was only known at first through one of his friends, a zealous English theologian [Dr. Gore], it was natural to retain a certain reserve. However, it turned out that there had really

been in this case (just as in the case of the aged Baer) one of those interesting psychological metamorphoses which I have described in chapter vi. of the *Riddle*. Romanes suffered a good deal from illness and grief at the loss of friends in his last years. In this condition of extreme depression and melancholy he fell under mystic influences which promised him rest and hope by belief in the supernatural. It is hardly necessary to point out to impartial readers that such a conversion as this does not shake his earlier monistic views. As in similar cases where deep emotional disturbance, painful experiences, and exuberant hope have clouded the judgment, we must still hold that it is the place of the latter, and not of the emotions or of any supernatural revelation, to attain a knowledge of the truth. But for such attainment it is necessary for the organ of mind, the phronema, to be in a normal condition.[1]

Of all the wonders of life, consciousness may be said to be the greatest and most astounding. It is true that to-day most physiologists are agreed that man's consciousness, like all his other mental powers, is a function of the brain, and may be reduced to physical and chemical processes in the cells of the cortex. Nevertheless, some biologists still cling to the metaphysical view that this "central mystery of psychology" is an insoluble enigma, and not a natural phenomenon. In face of this, I must refer the reader to the monistic theory of consciousness which I have given in chapter x. of the *Riddle*, and must insist that in this case again embryology is the best guide to a comprehension of the subject.

[1] English readers who are acquainted with Romanes's posthumous *Thoughts on Religion* will recognise the justice of this analysis. Romanes speaks expressly of the acceptance of Christianity entailing "the sacrifice of his intellect."—TRANS.

Sight is next to consciousness, in many respects, as one of the wonders of life. The well-known embryology of the eye teaches us how sight—the perception of images from the external world—has been gradually evolved from the simple sensitiveness to light of the lower animals, by the development of a transparent lens. In the same way the conscious soul, the internal mirror of the mind's own action, has been produced as a new wonder of life out of the unconscious associations in the phronema of our earlier vertebrate ancestors.

From this thorough and unprejudiced appreciation of the biology of the phronema it follows that the knowledge of truth, the aim of all science, is a natural physiological process, and that it must have its organs like all other psychic functions. These organs have been revealed to us so fully in the advance of biology during the last half-century that we may be said to have a generally satisfactory idea of the natural character of their organisation and action, though we are still far from enjoying a complete anatomical and physiological insight into their details. The most important acquisition we have made is the conviction that all knowledge was originally acquired *à posteriori* and from experience, and that its first sources are the impressions made on our organs of sense. Both these—the peripheral sense-organs—and the phronema, or central psychic organ, are subject to the law of substance; and the action of the phronema is just as reducible to chemical and physical processes as the action of the organs of sense.

In diametrical opposition to our monistic and empirical theory of knowledge, the prevailing dualistic metaphysics assumes that our knowledge is only partly empirical and *à posteriori*, and is partly quite independent of experience and *à priori*, or due to the original constitution of our

"immaterial" mind. The powerful authority of Kant has lent enormous prestige to this mystic and supernatural view, and the academic philosophers of our time are endeavouring to maintain it. A "return to Kant" is held to be the only means of salvation for philosophy; in my opinion it should be a return to nature. As a fact, the return to Kant and his famous theory of knowledge is an unfortunate "crab-walk" on the part of philosophy. Our modern metaphysicians regard the brain, as Kant did 120 years ago, as a mysterious, whitish-grey, pulpy mass, the significance of which as an instrument of the mind is very enigmatic and obscure. But for modern biology the brain is the most wonderful structure in nature, a compound of innumerable soul-cells or neurona. These have a most elaborate finer structure, are combined in a vast psychic apparatus by thousands of interlacing nerve-fibrils, and are thus fitted to accomplish the highest mental functions.

## First Table.

### ANTITHESIS OF THE TWO WAYS OF ATTAINING THE TRUTH.

| Monistic Theory of Knowledge. | Dualistic Theory of Knowledge. |
|---|---|
| 1. Knowledge is a natural process, not a miracle. | 1. Knowledge is a supernatural process, a miracle. |
| 2. Knowledge, as a natural process, is subject to the general law of substance. | 2. Knowledge, as a transcendental process, is not subject to the law of substance. |
| 3. Knowledge is a physiological process, with the brain for its anatomic organ. | 3. Knowledge is not a physiological, but a purely spiritual, process. |
| 4. The part of the human brain in which knowledge is exclusively engendered is a definite and limited part of the cortex, the phronema. | 4. The part of the human brain which seems to act as organ of knowledge is really only the instrument that allows the spiritual process to appear. |
| 5. The organ of knowledge, or the phronema, consists of the association-centres, and differs by its special histological structure from the neighbouring sensory and motor centres in the cortex, and it is in close relation with these. | 5. The organ of knowledge, or the phronema (the sum of the association-centres), is merely a part of the instrument of mind, like the neighbouring and correlated sensory and motor centres. |
| 6. The innumerable cells which make up the phronema—the phronetal cells—are the elementary organs of the cognitive process: the possibility of knowledge depends on their normal physical texture and chemical composition. | 6. The innumerable phronetal cells, as the microscopic elementary parts of the phronema, are, it is true, indispensable instruments of the cognitive process, but not its real factors—merely finer parts of its instrument. |
| 7. The physical process of knowledge consists in the combination or association of presentations, the first sources of which are the impressions transmitted to the sense-centres. | 7. The metaphysical process of knowledge consists in the combination or association of presentations, which are only partly traceable to sense-impressions, and are partly supersensual, transcendental processes. |
| 8. Hence all knowledge originally comes from experience, by means of the organs of sense; partly directly (direct experience, observation, and experiment of the present), partly indirectly (historical and indirectly transmitted past experiences). All knowledge (even mathematical) is of empirical origin and *à posteriori*. | 8. Hence knowledge is of two kinds: empirical and *à posteriori* knowledge, obtained by experience, and transcendental *à priori* knowledge, independent of experience. Mathematics especially belongs to the latter class, its axioms differing from empirical truths by their absolute certainty. |

## Chapter II.

## LIFE

Definition of life. Comparison with a flame. Organism and organisation. Machine theory of life. Organisms without organs: monera. Organisation and life of the chromacea. Stages of organisation. Complex organisms. Symbolic organisms. Organic compounds. Organisms and inorganic bodies compared in regard to matter, form, and function. Crystalloid and colloid substances. Life of crystals. Growth of crystals. Waves of growth. Metabolism. Catalysis. Fermentation. Biogenesis. Vital force. Old and new vitalism. Palavitalism. Antivitalism. Neovitalism.

As the object of this work is the critical study of the wonders of life, and a knowledge of the truth concerning them, we must first of all form a clear idea of the meaning of "life" and "wonder," or miracle. For thousands of years men have appreciated the difference between life and death, between living and lifeless bodies; the former are called organisms, and the latter known as inorganic bodies. Biology—in the widest sense—is the name of the science which treats of organisms; we might call the science which deals with the inorganic "abiology," abiotik, or anorgik. The chief difference between the two provinces is that organisms accomplish peculiar, periodically repeated, and apparently spontaneous movements, which we do not find in inorganic matter. Hence life may be conceived as a special process of movement. Recent study has shown that this is always connected with a particular chemical substance, *plasm*, and consists essentially in a circulation of matter, or *metabolism*. At

the same time modern science has shown that the sharp distinction formerly drawn between the organic and the inorganic cannot be sustained, but that the two kingdoms are profoundly and inseparably united.

Of all the phenomena of inorganic nature with which the life-process may be compared, none is so much like it externally and internally as the flame. This important comparison was made 2,400 years ago by one of the greatest philosophers of the Ionic school, Heraclitus of Ephesus—the same thinker who first broached the idea of evolution in the two words, *Panta rei*—all things are in a state of flux. Heraclitus shrewdly conceived life as a fire, a real process of combustion, and so compared the organism to a torch.

Max Verworn has lately employed this metaphor with great effect in his admirable work on general physiology, and has especially dealt with the comparison of the individual life-form with the familiar butterfly-shape of the gas-flame. He says:—

The comparison of life to a flame is particularly suitable for helping us to realise the relation between form and metabolism. The butterfly-shape of a gas-flame has a very characteristic outline. At the base, immediately above the burner, there is still complete darkness; over this is a blue and faintly luminous zone; and over this again the bright flame expands on either side like the wings of a butterfly. This peculiar form of the flame, with its characteristic features, which are permanent, as long as we do not interfere with the gas or the environment, is solely due to the fact that the grouping of the molecules of the gas and the oxygen at various parts of the flame is constant, though the molecules themselves change every moment. At the base of the flame the molecules of the gas are so thickly pressed that the oxygen necessary for their combustion cannot penetrate; hence the darkness we find here. In the bluish zone a few molecules of oxygen have combined with the molecules of the gas: we have a faint light as the result. But in the body of the flame the molecules of the gas are so freely combined with the oxygen of the atmosphere that we have a lively combustion. However, the exchange of matter (metabolism) between the outpouring gas and the surrounding air

is so regulated that we always find the same molecules in the same quantity at the same spot. Thus we get the permanent flame, with all its characteristics. But, if we alter the circulation by lessening the stream of gas, the shape of the flame changes, because now the disposition of the molecules on both sides is different. Thus the study of the gas-jet gives us, even in detail, the features we find in the structure of the cell.

The scientific soundness of this metaphor is all the more notable as the phrase, "the flame of life," has long been familiar both in poetry and popular parlance.

In the sense in which science usually employs the word "organism," and in which we employ it here, it is equivalent to "living thing" or "living body." The opposite to it, in the broad sense, is the anorganic or inorganic body. Hence the word "organism" belongs to physiology, and connotes essentially the visible life-activity of the body, its metabolism, nutrition, and reproduction.

However, in most organisms we find, when we examine their structure closely, that this consists of various parts, and that these parts are put together for the evident purpose of accomplishing the vital functions. We call them *organs*, and the manner in which they are combined, apparently on a definite plan, is their *organisation*. In this respect, we compare the organism to a machine in which someone has similarly combined a number of (lifeless) parts for a definite purpose, but according to a pre-conceived and rationally-initiated design.

The familiar comparison of an organism to a machine has given rise to very serious errors in regard to the former, and has, of late, been made the base of false dualistic principles. The modern "machine-theory of life" which is raised thereon demands an intelligent design and a deliberate constructing engineer for the origin of the organism, just as we find in the case of the machine. The organism is then very freely compared

to a watch or a locomotive. In order to secure the regular working of such a complicated mechanism, it is necessary to arrange for a perfect co-operation of all its parts, and the slightest accident to a single wheel suffices to throw it out of gear. This figure was particularly employed by Louis Agassiz (1858), who saw "an incarnate thought of the Creator" in every species of animal and plant. Of late years it has been much used by Reinke in the support of his theosophic dualism. He described God, or "the world-soul," as the "cosmic intelligence," but ascribes to this mystic immaterial being the same attributes that the catechism and the preacher give to the Creator of heaven and earth. He compares the human intelligence which the watch-maker has put into the elaborate structure of the watch with the "cosmic intelligence" which the Creator has put in the organism, and insists that it is impossible to deduce its purposive organisation from its material constituents. In this he entirely overlooks the immense difference between the "raw material" in the two cases. The "organs" of the watch are metallic parts, which fulfil their purpose in virtue only of their physical properties (hardness, elasticity, etc.). The organs of the living organism, on the other hand, perform their functions chiefly in virtue of their chemical composition. Their soft plasma-body is a chemical laboratory, the highly elaborate molecular structure of which is the historical product of countless complicated processes of heredity and adaptation. This invisible and hypothetical molecular structure must not (as is often done) be confused with the real and microscopically discoverable structure of the plasm, which is of great importance in the question of organisation. If one is disposed to assume for this molecular structure a simple chemical substance, a deliberate design, and an

"intelligent natural force" for cause, one is bound to do the same for powder, and say that the molecules of charcoal, sulphur, and saltpetre have been purposively combined to produce an explosion. It is well known that powder was not made according to a theory, but accidentally discovered in the course of experiment. The whole of this favourite machine-theory of life, and the far-reaching dualistic conclusions drawn from it, tumble to pieces when we study the simplest organisms known to us, the monera; for these are really organisms without organs—and without organisation!

I endeavoured in my *Generelle Morphologie* (1866) to draw the attention of biologists to these simplest and lowest organisms which have no visible organisation or composition from different organs. I therefore proposed to give them the general title of monera. The more I have studied these structureless beings—cells without nuclei!—since that time, the more I have felt their importance in solving the greatest questions of biology—the problem of the origin of life, the nature of life, and so on. Unfortunately, these primitive little beings are ignored or neglected by most biologists to-day. O. Hertwig devotes one page of his 300-page book on cells and tissues to them; he doubts the existence of cells without nuclei. Reinke, who has himself shown the existence of unnucleated cells among the bacteria (*beggiatoa*), does not say a word about their general significance. Bütschli, who shares my monistic conception of life, and has given it considerable support by his own thorough study of plasma-structures and the artificial production of them in oil and soapsuds, believes, like many other writers, that the "composition of even the simplest elementary organism from cell-nucleus and protoplasm" (the primitive organs of the cell) is indispensable.

These and other writers suppose that the nucleus has been overlooked in the protoplasm of the monera I have described. This may be true for one section of them; but they say nothing about the other section, in which the nucleus is certainly lacking. To this class belong the remarkable *chromacea* (*phycochromacea* or *cyanophycea*), and especially the simplest forms of these, the *chroococcacea* (*chroococcus*, *aphanocapsa*, *glœocapsa*, etc.). These plasmodomous (plasma-forming) monera, which live at the very frontier of the organic and inorganic worlds, are by no means uncommon or particularly difficult to find; on the contrary, they are found everywhere, and are easy to observe. Yet they are generally ignored because they do not square with the prevailing dogma of the cell.

I ascribe this special significance to the chromacea among all the monera I have instanced because I take them to be the oldest phyletically, and the most primitive of all living organisms known to us. In particular their very simple forms correspond exactly to all the theoretic claims which monistic biology can make as to the transition from the inorganic to the organic. Of the chroococcacea, the chroococcus, glœocapsa, etc., are found throughout the world; they form thin, usually bluish-green coats or jelly-like deposits on damp rocks, stones, bark of trees, etc. When a small piece of this jelly is examined carefully under a powerful microscope, nothing is seen but thousands of tiny blue-green globules of plasma, distributed irregularly in the common structureless mass. In some species we can detect a thin structureless membrane enclosing the homogeneous particle of plasm; its origin can be explained on purely physical principles by "superficial energy"—like the firmer surface-layer of a drop of rain, or of a globule of oil swimming

in water. Other species secrete homogeneous jelly-like envelopes—a purely chemical process. In some of the chromacea the blue-green colouring matter *(phyocyan)* is stored in the surface-layer of the particle of plasm, while the inner part is colourless—a sort of "central body." However, the latter is by no means a real, chemically and morphologically distinct, nucleus. Such a thing is completely lacking. The whole life of these simple, motionless globules of plasm is confined to their metabolism (or *plasmodomism*, chap. x.) and the resulting growth. When the latter passes a certain stage, the homogeneous globule splits into two halves (like a drop of quick-silver when it falls). This simplest form of reproduction is shared by the chromacea (and the cognate bacteria) with the chromatella or chromatophora, the green particles of chlorophyll inside ordinary plant-cells; but these are only parts of a cell. Hence no unprejudiced observer can compare these unnucleated and independent granules of plasm with real (nucleated) cells, but must conceive them rather as *cytodes*. These anatomic and physiological facts may easily be observed in the chromacea, which are found everywhere. The organism of the simplest chromacea is really nothing more than a structureless globular particle of plasm; we cannot discover in them any composition of different organs (or organella) for definite vital functions. Such a composition or organisation would have no meaning in this case, since the sole vital purpose of these plasma-particles is self-maintenance. This is attained in the simplest fashion for the individual by metabolism; for the species it is effected by self-cleavage, the simplest conceivable form of reproduction.

Modern histologists have discovered a very intricate and delicate structure in many of the higher unicellular

protists and in many of the tissue-cells of the higher animals and plants (such as the nerve-cells). They wrongly conclude that this is universal. In my opinion, this complication of the structure of the elementary organism is always a secondary phenomenon, the slow and gradual result of countless phylogenetic processes of differentiation, initiated by adaptation and transmitted to posterity by heredity. The earliest ancestors of all these elaborate nucleated cells were at first simple, unnucleated cytodes, such as we find to-day in the ubiquitous monera. We shall see more about them in the ninth and fifteenth chapters.

Naturally, this lack of a visible histological structure in the plasma-globule of the monera does not exclude the possession of an invisible molecular structure. On the contrary, we are bound to assume that there is such a structure, as in all albuminoid compounds, and especially all plasmic bodies. But we also find this elaborate chemical structure in many lifeless bodies; some of these, in fact, show a metabolism similar to that of the simplest organisms. We will return subsequently to this subject of catalysis. Briefly, the only difference between the simplest chromacea and inorganic bodies that have catalysis is in the special form of their metabolism, which we call plasmodomism (formation of plasm), or "carbon-assimilation." The mere fact that the chromacea assume a globular form is no sign whatever of a morphological vital process; drops of quick-silver and other inorganic fluids take the same shape when the individual body is formed under certain conditions. When a drop of oil falls into a fluid of the same specific gravity with which it cannot mix (such as a mixture of water and spirits of wine), it immediately assumes a globular shape. Inorganic solids usually take the form

of crystals instead. Hence the distinctive feature of the simplest organism, the plasma-particles of the monera, is neither anatomic structure nor a certain shape, but solely the physiological function of plasmodomism—a process of chemical synthesis.

The difference between the monera I have described and any higher organism is, I think, greater in every respect than the difference between the organic monera and the inorganic crystals. Nay, even the difference between the unnucleated monera (as cytodes) and the real nucleated cells may fairly be regarded as greater still. Even in the simplest real cell we find the distinction between two different organella, or "cell-organs," the internal nucleus and the outer cell-body. The *caryoplasm* of the nucleus discharges the functions of reproduction and heredity; the *cytoplasm* of the cell-body accomplishes the metabolism, nutrition, and adaptation. Here we have, therefore, the first, oldest, and most important process of division of labour in the elementary organism. In the unicellular protists the organisation rises in proportion to the differentiation of the various parts of the cell; in the tissue-forming histona it rises again in proportion to the distribution of work (or ergonomy) among the various organs. Darwin has given us in his theory of selection a mechanical explanation of the apparent design and purposiveness in this.

In order to have a correct monistic conception of organisation, it is important to distinguish the individuality of the organism in its various stages of composition. We shall treat this important question, about which there is a good deal of obscurity and contradiction, in a special chapter (vii.). It suffices for the moment to point out that the unicellular beings (protists) are

simple organisms both in regard to morphology and physiology. On the other hand, this is only true in the physiological sense of the histona, the tissue-forming animals and plants. From the morphological point of view they are made up of innumerable cells, which form the various tissues. These histonal individuals are called sprouts in the plant world and persons in the animal world. At a still higher stage of organisation we have the trunk or stem (cormus), which is made up of a number of sprouts or persons, like the tree or the coral-stem. In the fixed animal stems the associated individuals have a direct bodily connection, and take their food in common; but in the social aggregations of the higher animals it is the ideal link of common interest that unites the individuals, as in swarms of bees, colonies of ants, herds of mammals, etc. These communities are sometimes called "animal-states." Like human polities, they are organisms of a higher type.

However, in order to avoid misunderstanding, we must take the word "organism" in the sense in which most biologists use it—namely, to designate an individual living thing, the material substratum of which is plasm or "living substance"—a nitrogenous carbon-compound in a semi-fluid condition. It leads to a good deal of misunderstanding when separate functions are called organisms, as is done sometimes in speaking of the soul or of speech. It would be just as correct to call seeing or running an organism. It is advisable also in scientific treatises to refrain from calling inorganic compounds as such "organisms," as, for instance, the sea or the whole earth. Such names, having a purely symbolical value, may very well be used in poetry. The rhythmic wave-movement of the ocean may be regarded as its respiration, the surge as its voice, and so on. Many scientists

(like Fechner) conceive the whole earth with all its organic and inorganic contents as a gigantic organism, whose countless organs have been arranged in an orderly whole by the world-reason (God). In the same way the physiologist, Preyer, regards the glowing heavenly bodies as "gigantic organisms, whose breath is, perhaps, the glowing vapour of iron, whose blood is liquid metal, and whose food may be meteorites." The danger of this poetic application of the metaphorical sense of organism is very well seen in this instance, as Preyer builds on it a quite untenable hypothesis of the origin of life (see chap. xv.).

In the wider sense the word "organic" has long been used in chemistry as an antithesis to inorganic. By organic chemistry is generally understood the chemistry of the compounds of carbon, that element being distinguished from all the others (some seventy-eight in number) by very important properties. It has, in the first place, the property of entering into an immense variety of combinations with other elements, and especially of uniting with oxygen, hydrogen, nitrogen, and sulphur to form the most complicated albuminoids (see the *Riddle*, chap. xiv.). Carbon is a biogenetic element of the first importance, as I explained in my carbon-theory in 1866. It might even be called "the creator of the organic world." At first these organogenetic compounds do not appear in the organism in organised form—that is to say, they are not yet distributed into organs with definite purposes. Such organisation is a result, not the cause, of the life-process.

I have already shown in the fourteenth chapter of the *Riddle* (and at greater length in the fifteenth chapter of my *History of Creation*) that the belief in the essential unity of nature, or the monism of the cosmos, is of the

greatest importance for our whole system. I gave a very thorough justification of this cosmic monism in 1866. In the fifth chapter of the *Generelle Morphologie* I considered the relation of the organic to the inorganic in every respect, pointing out the differences between them on the one hand, and their points of agreement in matter, form, and force on the other. Nägeli some time afterwards declared similarly for the unity of nature in his able *Mechanisch-physiologische Begründung der Abstammungslehre* (1884). Wilhelm Ostwald has recently done the same, from the monistic point of view of his system of energy, in his *Naturphilosophie*, especially in the sixteenth chapter. Without being acquainted with my earlier work, he has impartially compared the physico-chemical processes in the organic and inorganic worlds, partly adducing the same illustrations from the instructive field of crystallisation. He came to the same monistic conclusions that I reached thirty-six years ago. As most biologists continue to ignore them, and as, especially, modern vitalism thrusts these inconvenient facts out of sight, I will give a brief summary once more of the chief points as regards the matter, form, and forces of bodies.

Chemical analysis shows that there are no elements present in organisms that are not found in inorganic bodies. The number of elements that cannot be further analysed is now put at seventy-eight; but of these only the five organogenetic elements already mentioned which combine to form plasm—carbon, oxygen, hydrogen, nitrogen, and sulphur—are found invariably in living things. With these are generally (but not always) associated five other elements—phosphor, potassium, calcium, magnesium, and iron. Other elements may also be found in organisms; but there is not a single biological element that is

not also found in the inorganic world. Hence the distinctive features which separate the one from the other can be sought only in some special form of combination of the elements. And it is carbon especially, the chief organic element, that by its peculiar affinity enters into the most diverse and complicated combinations with other elements, and produces the most important of all substances, the albuminoids, at the head of which is the living plasm (*cf.* chap. vi.).

An indispensable condition of the circulation of matter (metabolism) which we call life is the physical process of osmosis, which is connected with the variations in the quantity of water in the living substance and its power of diffusion. The plasm, which is of a spongy or viscous consistency, can take in dissolved matter from without (endosmosis) and eject matter from within (exosmosis). This absorptive property (or "imbibition-energy") of the plasm is connected with the colloidal character of the albuminoids. As Graham has shown, we may divide all soluble substances into two groups in respect of their diosmosis—crystalloids and colloids. Crystalloids (such as soluble salt and sugar) pass more easily into water through a porous wall than colloids (such as albumen, glue, gum, caramel). Hence we can easily separate by dialysis two bodies of different groups which are mixed in a solution. For this we need a flat bottle with side walls of india-rubber and bottom of parchment. If we let this vessel float in a large one containing plenty of water, and pour a mixture of dissolved gum and sugar into the inner vessel, after a time nearly all the sugar passes through the parchment into the water, and an almost pure solution of gum remains in the bottle. This process of diffusion, or osmosis, plays a most important part in the life of all organisms; but it is by no means

peculiar to the living substance, any more than the absorptive or viscous condition is. We may even have one and the same substance—either organic or inorganic —in both conditions, as crystal or as colloid. Albumen, which usually seems to be colloidal, forms hexagonal crystals in many plant-cells (for instance, in the aleuron-granules of the endosperm), and tetrahedric hœmoglobin-crystals in many animal-cells (as in the blood corpuscles of mammals). These albuminoid crystals are distinguished by their capacity for absorbing a considerable quantity of water without losing their shape. On the other hand, mineral silicon, which appears as quartz in an immense variety (more than 160) of crystalline forms, is capable in certain circumstances (as metasilicon) of becoming colloidal and forming jelly-like masses of glue. This fact is the more interesting because silicium behaves in other ways very like carbon, is quadrivalent like it, and forms very similar combinations. Amorphous (or non-crystalline) silicium (a brown powder) stands in relation to the black metallic silicon-crystals just as amorphous carbon does to graphite-crystals. There are other substances that may be either crystalloid or colloid in different circumstances. Hence, however important colloidal structure may be for the plasm and its metabolism, it can by no means be advanced as a distinctive feature of living matter.

Nor is it possible to assign an absolute distinction between the organic and the inorganic in respect of morphology any more than of chemistry. The instructive monera once more form a connecting bridge between the two realms. This is true both of the internal structure and the outward form of both classes of bodies—of their individuality (chap. vii.) and their type (chap. viii.). Inorganic crystals correspond

morphologically to the simplest (unnucleated) forms of the organic cells. It is true that the great majority of organisms seem to be conspicuously different from inorganic bodies by the mere fact that they are made up of many different parts which they use as organs for definite purposes of life. But in the case of the monera there is no such organisation. In the simplest cases (chromacea, bacteria) they are structureless, globular, discoid, or rod-shaped plasmic individuals, which accomplish their peculiar vital function (simple growth and sub-division) solely by means of their chemical constitution, or their invisible molecular structure.

The comparison of cells with crystals was made in 1838 by the founders of the cell-theory, Schleiden and Schwann. It has been much criticised by recent cytologists, and does not hold in all respects. Still it is of importance, as the crystal is the most perfect form of inorganic individuality, has a definite internal structure and outward form, and obtains these by a regular growth. The external form of crystals is prismatic, and bounded by straight surfaces which cut each other at certain angles. But the same form is seen in the skeletons of many of the protists, especially the flinty shells of the diatomes and radiolaria; their silicious coverings lend themselves to mathematical determination just as well as the inorganic crystals. Midway between the organic plasma-products and inorganic crystals we have the *bio-crystals*, which are formed by the united plastic action of the plasm and the mineral matter—for instance, the crystalline flint and chalk skeletons of many of the sponges, corals, etc. Further, by the orderly association of a number of crystals we get compound crystal groups, which may be compared to the communities of protists—for instance, the branching

ice-flowers and ice-trees on the frozen window. To this regular external form of the crystal corresponds a definite internal structure which shows itself in their cleavage, their stratified build, their polar axes, etc.

If we do not restrict the term "life" to organisms properly so-called, and take it only as a function of plasm, we may speak in a broader sense of the life of crystals. This is seen especially in their growth, the phenomenon which Baer regarded as the chief character of all individual development. When a crystal is formed in a matrix, this is done by attracting homogeneous particles. When two different substances, A and B, are dissolved in a mixed and saturated solution, and a crystal of A is put in the mixture, only A is crystallised out of it, not B; on the other hand, if a crystal of B is put in, A remains in solution and B alone assumes the solid crystalline form. We may, in a certain sense, call this choice *assimilation*. In many crystals we can detect internally an interaction of their parts. When we cut off an angle in a forming crystal, the opposite angle is only imperfectly formed. A more important difference between the growth of crystals and monera is that the former only grow by *apposition*, or the deposit of fresh solid matter at their surface; while the monera grow, like all cells, by *intussusception*, or the taking of new matter into their interior. But this difference is easily explained by their difference in consistency, the crystal being solid and the plasm semi-fluid. Moreover, the difference is not absolute; there are intermediary stages between apposition and intussusception. A colloid globule suspended in a salt solution in which it is not dissolved may grow by intussusception.

It was once the custom to restrict sensation and movement to animals, but they are now recognised to be

present in nearly all living matter. They are, in fact, not altogether lacking in crystals, as the molecules move in crystallisation in definite directions, and unite according to fixed laws; they must, therefore, also possess sensation, as we could not otherwise understand the attraction of the homogeneous particles. We find in crystallisation, as in every chemical process, certain movements which are unintelligible without sensation—unconscious sensation, of course. In this respect, also, then, the growth of all bodies follows the same laws (*cf.* chapters xiii. and xv.).

The growth of a crystal is restricted like the growth of a moneron or of any cell. If the limit is passed and the conditions remain favourable to growth, we find an instance of that excessive or *transgressive* growth which we call reproduction in the case of living individuals. But we find just the same kind of extension in the inorganic crystal. Every crystal grows in a supersaturated medium only up to a definite size, which is determined by its chemical-molecular constitution. When this limit is reached a number of small crystals appear on the large one. Ostwald, who has made a thorough comparison of the process of growth in crystals and monera, especially notices the striking analogy between a bacterium (a plasmophagous moneron) growing and multiplying in its nutritive fluid and a crystal in its matrix. When the water slowly evaporates from a supersaturated solution of Glauber-salt, not only does a crystal slowly grow in it, but several young crystals appear on it. The analogy with the bacterium multiplying in its nutritive fluid can even be followed as far as its permanent forms or "spores." This quiescent form is assumed by the bacterium if its supply of food is exhausted; if fresh food is added, the multiplication

by cleavage begins again. In the same way the crystals of Glauber-salt begin to decay when the solution is evaporated; they lose their crystal water, but not their power of multiplication. Even the amorphous powder of the salt causes again the formation of new watery crystals when put in a supersaturated solution. But the powder loses this property when it is heated, just as the dormant forms (or spores) of the bacteria lose their power of germination.

The exhaustive comparison of the growth of crystals and monera (as the simplest forms of unnucleated cells) is important, because it shows the possibility of tracing the vital function of reproduction—which had usually been regarded as a quite special " wonder of life "—to purely physical conditions. The division of the growing individual into several young ones must necessarily take place when the natural limit of growth has been passed, and when the chemical composition of the growing body and the cohesion of its molecules allow no further enlargement by the assumption of new matter. In order to illustrate the limit of this transgressive growth by a simple physical example, Ostwald imagines a ball placed in a small flat basin, built up high on one side. The ball is in a state of equilibrium in the basin; when it is lightly pushed aside it always returns to its original position. But when the push goes beyond a certain point, and the ball is thrust over the side of the basin, the balance is lost; the ball does not return, but falls to the ground. The crystal behaves just in the same way in a supersaturated solution when it exercises its power of forming new crystals; and it is just the same with the bacterium growing in a nutritive fluid when it passes the limit of its volume of growth, and divides into two individuals.

As we can find no morphological and little physiological difference between the living and non-living, we must look upon metabolism as the chief characteristic of organic life. This process causes the conversion of food into plasm; it is determined by the vital force itself, and is the formation of new living matter. It thus effects the nutrition and growth of the living being, and therefore its reproduction, which is merely transgressive growth. As I shall describe this metabolism fully in the tenth chapter, I will do no more here than emphasise the fact that this vital process also has analogies in inorganic chemistry, in the curious process of catalysis, especially that form of it which we call fermentation.

The distinguished chemist Berzelius discovered in 1810 the remarkable fact that certain bodies, by their mere presence, apart from their chemical affinity, set other bodies in decomposition or composition without being themselves affected. Thus, for instance, sulphuric acid changes the starch in sugar without undergoing any alteration itself. Finely ground platinum brought in contact with hydrogen-superoxide divides it into hydrogen and oxygen. Berzelius called this process *catalysis*; Mitscherlich, who discovered the cause of it to be the peculiar surface-action of many bodies, gave it the name of "contact-action." It was afterwards discovered that catalysis of this kind is very general, and that a special form of it—fermentation—plays an important part in the life of organisms.

This special form of contact-action which we call fermentation is always effected by catalytic bodies of the albuminoid class, and, in fact, of the group of non-coagulable proteins which are known as peptones. They have—in however small a quantity—the capacity to throw into decomposition large masses of organic matter

(in the form of yeast, putrid matter, etc.) without themselves taking part in the decomposition. When these ferments are free and unorganised they are called enzyma, in opposition to organised ferments (bacteria, yeast-fungi, etc.); though the catalytic action of the latter also consists essentially in the production of enzyma. The recent investigations of Verworn, Hofmeister, Ostwald, etc., have shown that these catalyses play everywhere an important part in the life of the plasm. Many recent chemists and physiologists are of opinion that plasm is a *colloid catalysator*, and that all the varied activities of life are connected with this fundamental vital chemistry. Thus Franz Hofmeister (1901) says in his excellent work on *The Chemical Organisation of the Cell*:—

> The belief that the agents of the chemical transformation in the cell are catalysators of a colloid nature is in complete accord with other facts that have been directly ascertained. What else are the chemists' ferments but colloid catalysators? The idea that the ferments are the essential chemical agency in the cell is calculated to meet the difficulty which arises from the smallness of the cell in appreciating its chemical processes. However large we suppose the colloid ferment molecules to be, there is room for millions of them in the smallest cell.

In the same way Ostwald attributes the greatest significance to catalysis in connection with the vital processes, and seeks to explain them on his theory of energy by reference to the duration of chemical processes. In the discourse "On Catalysis" that he delivered at Hamburg in 1901 he says:—

> We must recognise the enzyma as catalysators that arise in the organism during the life of the cells, and by their action relieve the living being of the greater part of its duties. Not only are digestion and assimilation controlled by enzyma from first to last, but the fundamental vital action of most organisms, the production of the necessary chemical energy by combustion at the expense of the oxygen in the air, takes place with the explicit co-operation of enzyma, and would be impossible

without them. Free oxygen is, as is well known, a very inert body at the temperature of the living body, and the maintenance of life would be impossible without some acceleration of its rate of reaction.

In his further observations on catalysis and metabolism he says that they are both equally subject to the physico-chemical laws of energy.

Max Verworn has given us a very searching analysis of the molecular process in the catalytic aspect of metabolism in his *Biogen Hypothesis* (1903), "a critical and experimental study of the processes in living matter." He simplifies the catalytic theory of the enzyma by tracing all the phenomena of life to the catalytic metabolism of one single chemical compound, the plasm, and regards its active molecules, the biogens, as the ultimate chemical factors of the vital process. While the enzyma hypothesis assumes that there are in each cell a great number of different enzyma which are all co-ordinated, and each of which only performs its little special work, the biogen hypothesis deduces all the vital phenomena from one compound, the biogenetic plasm ; and thus the biogen molecules, which increase by division into parts, are the sole factors of biological catalysis. Verworn also points out the analogy between this enzymatic process of metabolism and the inorganic processes of catalysis—for instance, in the manufacture of English sulphuric acid. A small and constant quantity of nitro-muriatic acid, with the aid of air and water, converts an unlimited mass of sulphuretted acid into sulphuric acid without being changed itself ; the molecule of the nitro-muriatic acid breaks up steadily by the giving-off of oxygen, and is then restored by the assumption of oxygen.

The manifold and changeful phenomena of life and their sudden extinction at death seem to every thoughtful

man to be something so wonderful and so different from all the changes in inorganic nature that from the very beginning of biological philosophy special forces were assumed to explain it. This was particularly due to the remarkable orderly structure of the organism and the apparent purposiveness of the vital processes. Hence, in earlier days a special organic force *(archæus insitus)* was assumed, controlling the individual life and pressing the "raw forces" of inorganic matter into its service. In the same way a special formative impulse was supposed to preside over the wonderful processes of development. When physiology began to win its independence, about the middle of the eighteenth century, it explained the peculiar features of organic life by a specific vital force. The idea was generally received, and Louis Dumas endeavoured thoroughly to establish it at the beginning of the nineteenth century (*cf.* chap. iii. of the *Riddle*).

As the theory of a vital force, or vitalism, plays an important part in the study of the wonders of life, has undergone the most curious modifications in the course of the nineteenth century, and has been lately revived with great force, we must give a short account of it in its various forms. The phrase can be interpreted in a monistic sense, if we understand by it the sum of the forms of energy which are especially distinctive of the organism, particularly metabolism and heredity. In this we pass no opinion on their nature, and do not say that they are specifically different from the forces of inorganic nature. We might call this monistic conception "physical vitalism." However, the usual metaphysical vitalism affirms in a thoroughly dualistic sense that the vital force is a teleological and super-mechanical principle, is essentially different from the ordinary forces of nature, and of a transcendental character.

The special form in which this theory of a supernatural vital force has been presented for the last twenty years is often called Neovitalism; we might call the older form, by contrast, Palavitalism.

The older idea of the vital force as a special energy could very well be accepted in the first third of the nineteenth century, and in the eighteenth, because the physiology of the time was destitute of the most important aids to the founding of a mechanical theory. There was then no such thing as the cell-theory or as physiological chemistry; ontogeny and paleontology were still in their cradles. Lamarck's theory of descent (1809) had been done to death, like his fundamental principle: "Life is only an elaborate physical phenomenon." Hence we can easily understand how physiologists acquiesced in the vitalist hypothesis up to 1833, and supposed the wonders of life to be enigmatic phenomena that escaped physical explanation.

But the position of Palavitalism changed in the second third of the nineteenth century. In 1833 appeared Johannes Müller's classical *Manual of Human Physiology*, in which the great biologist not only made a comparative study of the vital phenomena in man and the animals, but sought to provide a sound basis for it in all its sections by his own observations and experiments. It is true that Müller retained to the last (1858) the current idea of a vital force, as the supreme regulator of all the vital activities. However, he did not regard it as a metaphysical principle (like Haller, Kant, and their followers), but as a natural force, subject, like all others, to fixed chemical and physical laws, and subordinate to the whole. In his comprehensive study of every single vital function—the organs of sense and the nervous system, metabolism and the action of the heart, speech

and reproduction—Müller endeavoured above all to establish, by close observation of the facts and careful experiments, the regularity of the phenomena, and to explain their development by a comparison of the higher and lower forms. Hence Johannes Müller is wrongly described—as he has been of late—as a vitalist; he was rather the first physiologist to provide a physical foundation for the current metaphysical vitalism. He really gives an indirect proof of the reverse theory, as E. Dubois-Reymond rightly observed in his brilliant memorial speech. In the same way Schleiden (1843) cut the ground from under vitalism in botany. By his cell-theory (1838) he showed the unity of the multicellular organism to be the resultant of the functions of all the cells which compose it.

The physical explanation of the vital processes and the rejection of Palavitalism were general in the last third of the nineteenth century. This was due most of all to the great advance in experimental physiology, which Carl Ludwig and Felix Bernard led as regards the animal body, and Julius Sachs and Wilhelm Preyer for the plant. While these and other physiologists used the remarkable results of modern physics and chemistry in the experimental study of the vital functions, and sought to determine their complicated course in terms of mass and weight and formulate their discoveries as mathematically as possible, they brought a great number of the wonders of life under the same fixed laws that were recognised in the physics and chemistry of the inorganic world. On the other hand, vitalism met with a powerful opponent in Charles Darwin, who solved, by his theory of selection, one of the most obscure biological problems, the constantly-repeated question: How can we give a mechanical

explanation of the orderly structures of the living being? How was this ingenious machine of the animal or plant body unconsciously produced by natural means, without supposing that some intelligent artificer or creator had deliberately designed and produced it?

The further development of Darwin's theory of selection in the last four decades, and the increasing support which has been given to the theory of descent in the great advance of ontogeny, phylogeny, comparative anatomy, and physiology, did much to establish the monistic conception of life. It took the shape more and more of a definite anti-vitalism. Hence it is strange to find that in the course of the last twenty years the old vitalism that everybody had thought dead has lifted up its head once more, though in a new and modified form.[1] This modern vitalism comprises two essentially different tendencies.

The partisans of the modern vital force are divided into two groups, which may be designated the sceptical and the dogmatic. Sceptical Neovitalism was first formulated by Bunge of Basle (1887) in the introduction to his *Manual of Physiological Chemistry*. While he granted the possibility of a full explanation of one part of the vital phenomena by mechanical causes, or the physical and chemical forces of lifeless nature, he rejected it for the other half, especially for psychic activities. He insists that the latter cannot be explained mechanically, and that there is nothing analogous to them in

[1] This refers almost entirely to Germany. The reader will remember that, when Lord Kelvin endeavoured to make theosophic capital out of this temporary confusion in German science, he was immediately silenced by the leading biologists of this country, Professor E. Ray-Lankester (for zoology), Sir W. T. Thiselton-Dyer (for botany), and Sir J. Burdon-Sanderson (for physiology), who sharply rejected vitalism.—TRANS.

inorganic nature; only a supra-mechanical vital force can produce them, and this is transcendental and beyond the range of scientific inquiry. Much the same was said later by Rindfleisch (1888), more recently by Richard Neumeister in his *Studies of the Nature of Vital Phenomena* (1903), and by Oscar Hertwig in the lecture on "The Development of Biology in the Nineteenth Century," which he delivered at Aachen in 1900.

This sceptical Neovitalism is far surpassed by the dogmatic system, the chief actual representatives of which are the botanist Johannes Reinke and the metaphysician Hans Driesch. The vitalist writings of the latter, which are devoid of any grasp of historical development, have gained a certain vogue through the extraordinary arrogance of their author and the obscurity of his mystic and contradictory speculations. Reinke, on the other hand, has presented his transcendental dualism in clever and attractive form in two works which deserve notice on account of their consistent dualism. In the first of these, *The World as Reality* (1899), Reinke gives us "the outline of a scientific theory of the universe." The second work (1901) has the title, *Introduction to Theoretical Biology*. The two works have the same relation to each other as my *Riddle of the Universe* and the present supplementary volume. As our philosophic convictions are diametrically opposed in the main issues, and as we both think ourselves consistent in developing them, the comparison of them is not without interest in the great struggle of beliefs. Reinke is an avowed supporter of dualism, theism, and teleology. He reduces all the phenomena of life to a supernatural miracle.

## Second Table.

### ANTITHESIS OF THE MONISTIC AND DUALISTIC THEORIES OF ORGANIC LIFE.

| Monistic Theory of Life. (Biophysics.) | Dualistic Theory of Life. (Vitalism.) |
|---|---|
| 1. The phenomena of life are merely functions of plasm, determined by the physical, chemical, and morphological character of the living matter. | 1. The phenomena of life are wholly or partly independent of the plasm, and determined by a special immaterial force, the vital force *(vis vitalis)*. |
| 2. The energy of the plasm (as the sum-total of the forces which are connected with the living matter) is subject to the general laws of physics and chemistry. | 2. The energy of the plasm is wholly or partly subject to the immaterial vital force, which controls and directs the physical and chemical forces of the living matter. |
| 3. The obvious regularity of the vital processes and the organisation they produce are the outcome of natural evolution; their physiological factors (heredity and adaptation) are subject to the law of substance. | 3. The general regularity in the organisation and in the vital processes it accomplishes is the outcome of conscious creation; it can only be explained by intelligent immaterial forces, which are not subject to the law of substance. |
| 4. All the various functions have thus been mechanically produced, orderly structures having been created by adaptation and transmitted to posterity by heredity. | 4. All the various functions of organisms have been produced by design, the historical evolution (or phyletic transformation) being directed to a preconceived ideal end. |
| 5. Nutrition is a physico-chemical process, the metabolism of which has an analogy in inorganic catalysis. | 5. Nutrition is an inexplicable miracle of life, and cannot be understood by chemical and physical processes. |
| 6. Reproduction is a mechanical consequence of transgressive growth, analogous to the elective multiplication of crystals. | 6. Reproduction is an inexplicable miracle of life, without any analogy in inorganic nature. |
| 7. The movement of organisms is, in every form, not essentially different from the movements of inorganic dynamos. | 7. The movement of organisms is an inexplicable metaphysical miracle of life, specifically different from all inorganic movements. |
| 8. Sensation is a general form of the energy of substance, not specifically different in sensitive organisms and irritable inorganic objects (such as powder, dynamite). There is no such thing as an immaterial soul. | 8. The sensation of organisms can only be explained by ascribing a soul to them, an immaterial, immortal being that only dwells for a time in the body. After death this spirit lives an independent life. |

## Chapter III.

# MIRACLES

Miracle and natural law. Belief in miracles of savages (fetichism), of semi-civilised (idolatry), of civilised (theism), and of educated people (dualism). Religious belief in miracles. Apostles' Creed. Article relating to creation. Article relating to redemption. Article relating to immortality. Philosophic belief in miracles. Academic thinkers and Freethinkers. Dualism of Plato and Kant. Belief in miracles in the nineteenth century, in modern metaphysics, theology, and politics.

In ordinary parlance the word "miracle" means a number of different things. We say a phenomenon is miraculous or wonderful[1] when we cannot explain it and trace its causes. But we say a natural object or a work of art is wonderful when it is unusually beautiful and imposing—when it passes the ordinary limits of our experience. In this work I do not take the word in this relative sense, but in the absolute sense in which a phenomenon is said to transcend the limits of natural law and lie beyond the range of rational explanation. In this sense it means the same as "supernatural" or "transcendental." We can know natural phenomena by our reason and bring them within our cognisance. The miraculous can only be accepted on faith.

[1] The German word *wunder* corresponds equally to the English "miracle" and "wonder." It has seemed necessary to translate it "wonder" in the title of the work, but frequently as "miracle" in this chapter.—Trans.

The belief in supernatural miracles is in contradiction to pure reason, which lays the foundations of all science. Kant, who won so great a vogue for the term "pure reason," understood by this originally "reason as independent of experience." The phrase was used in a narrower sense subsequently to express independence of dogma and prejudice, as the base of pure and unprejudiced science. In this sense we oppose pure reason to superstition.

I have dealt in the sixteenth chapter of the *Riddle* with the important question of the relations of knowledge and faith. But I must return to the subject here, as what I said has given rise to a good deal of misunderstanding and criticism. I by no means claimed, as my opponents allege, to "know everything," or to have solved every problem. In fact, I said repeatedly that there are narrow limits to our knowledge, and always will be. I had also expressly stated that the irresistible impulse to learn in the intelligent man, or reason's constant demand to know causes, presses us to fill up the gaps in our knowledge by faith. But I had at the same time pointed out the contrast between scientific (natural) and religious (supernatural) faith. The one leads us to form hypotheses and theories; the other ends in myths and superstition. Scientific faith fills the gaps in our knowledge of natural law with temporary hypotheses; but mystic religious faith contradicts natural law, and transcends its limits in the form of a belief in miracles.

The great triumph of the progress of science in the nineteenth century, its theoretical value in the formation of a rational philosophy of life, and its practical value on the various sides of modern civilisation, consist, above all, in the absolute recognition of fixed natural laws.

That relation of things to each other, which we call causation, makes it possible for us to understand and explain facts. We feel that our thirst for a knowledge of the causes of things is contented when science points out the "sufficient reason" of them. In the whole province of inorganic cosmology natural law is now generally recognised to be all-powerful; in astronomy, geology, physics, and chemistry all phenomena are reduced to fixed laws, and in the long run to the all-embracing law of substance, the great law of the conservation of matter and force (*Riddle*, chap. xii.).

It is otherwise in biology, or the organic section of cosmology. Here we still find miracles set up in opposition to the law of substance, and the transgression of natural laws by supernatural forces. The belief in miracles of this kind, which pure reason calls superstition, is still very widespread; much more prevalent than is usually thought. For my part, I hold that superstition and unreason are the worst enemies of the human race, while science and reason are its greatest friends. Hence it is our duty and task to attack the belief in miracles wherever we find it, in the interest of the race. We have to prove that the reign of natural law extends over the whole world of phenomena as far as we can reach it. A general survey of the history of faith on the one hand and of science on the other clearly shows that the advance of the latter has always been accompanied by an increasing knowledge of fixed natural laws and the shrinking of superstition into an ever-lessening area. To-day we convince ourselves of this by an impartial examination of mental culture at the various stages of civilisation. For this purpose I take the four chief stages of mental development which Fritz Schultze has given in his *Physiology of Uncivilised*

*Races*, and Alexander Sutherland in his work, *On the Origin and Growth of the Moral Instinct*:—1, savages; 2, barbarians; 3, civilised races; 4, educated races (*cf.* chap. i.).

The mental life of savages rises little above that of the higher mammals, especially the apes, with which they are genealogically connected. Their whole interest is restricted to the physiological functions of nutrition and reproduction, or the satisfaction of hunger and thirst in the crudest animal fashion. Without fixed habitation, constantly struggling for existence, they live on the raw produce of nature—fruits, the roots of wild plants, and the animals they fish in the water or catch on land. Their intelligence moves within the narrowest bounds, and one can no more (or no less) speak of their reason than of that of the more intelligent animals. Of art and science there is no question. Their impulse to discover causes is satisfied with the simplest association of phenomena which have a merely external connection, but no intimate relation to each other. Thus arises their *fetichism*, that irrational trust in fetiches which Fritz Schultze has traced to four distinct causes: their false estimate of the value of an object, their anthropomorphic conception of nature, the imperfect association of their ideas, and the strength of their emotions, especially hope and fear. Any favourite object, a stone or a bone, may work miracles as a fetich and exercise all kinds of good or evil influence, and is therefore honoured, feared, and worshipped. At first the worship was paid to the invisible spirit that dwelt in the particular object; but it was often transferred afterwards to the dead object itself. Among the different savage races the belief in fetiches presents a number of stages, corresponding to the beginnings of reason. The lowest stage is found in

the lowest races, such as the Veddahs of Ceylon, the Andaman Islanders, Bushmen, and Akkas (of New Guinea). A somewhat higher stage is met in the middle races (Australian negroes, Tasmanians, Hottentots, and Tierra del Fuegians); and a still higher intellectual development is shown by the next group (most of the Indians of North and South America, the aboriginal inhabitants of India, etc.). Modern comparative ethnography and evolution and pre-historic and anthropological research have shown us that our own ancestors, ten thousand and more years ago, were (like the prehistoric ancestors of all races of men) savages, and that their earliest belief in miracles was a crude fetichism.

By barbarians we understand the races that are found between savage and civilised peoples. They show the first beginnings of civilisation, and are superior to savages chiefly in the possession of agriculture and the keeping of cattle. They make a provident use of the productive forces of organic nature, artificially produce large quantities of food, and are thus enabled by the abundance of food to turn their minds to other interests. We find that they have the rudiments of art and science. Their religion does not at first rise much above fetichism, but soon reaches the stage of animism, lifeless objects in nature being credited with souls. Worship is no longer paid to favourite dead objects (stones, bones, etc.), but generally to living things, trees and animals, and especially to images of gods which have the form of animals or men, and are believed to possess souls. As demons or spirits, these have a great influence on the fortunes of men. At first this soul is conceived to be purely material; it disappears at the death of the body and lives apart. As the breathing and the beat of the pulse and heart cease when a man dies, the seat of the

soul is thought to be the lungs, heart, or some other part of the body. The idea of the immortality of the soul takes on innumerable forms among them, like the belief in the miracles which are worked by the gods, demons, spirits, etc. Evolution again points out a long gradation of forms of faith, if we compare the lower, middle, and higher races.

Civilised races are distinguished from barbaric by the formation of states with an extensive division of labour. The social organism is not only larger and more powerful, but is capable of a greater variety of achievements, the functions of the various states and classes of workers being more highly differentiated and mutually complementary (like the cells and tissues in the higher animal body of the metazoa). Nutrition is easier and more luxurious. Art and science are well developed. A great advance is seen in regard to religion, the numerous gods being generally conceived as man-like spirits, and finally subordinated to a chief god. The belief in miracles flourishes greatly in poetry; in philosophy it is more and more restricted. In the end, the working of miracles is limited monotheistically to one god, or to his priests and other men to whom he communicates the power.

Modern civilisation in the narrower sense, as a contrast to the older civilisation, opens, in my opinion, at the beginning of the sixteenth century. At that time took place some of the greatest achievements of human thought among civilised peoples, and these broke the chains of tradition and gave a fresh impetus to progress. Men's own mental outlook was widened by the system of Copernicus; and the Reformation freed them from the yoke of the papacy. Shortly before, the discovery of the new world and the circumnavigation of the globe had convinced men of the rotundity of the earth; geography,

natural history, medicine, and other sciences gained inspiration and independence; printing and engraving provided an important means of spreading the new knowledge. This fresh impetus was chiefly of service to philosophy, which now more and more rejected the dictation of the Church and superstition; though it was far from casting off the fetters altogether. This was not generally possible until the nineteenth century, when empirical science assumed an enormous importance, and in the ensuing period of speculation the physical conception of the world gained more and more on the metaphysical. Pure knowledge, thus grounded on science, entered into sharper conflict than ever with religious faith. If, as in the preceding cases, we distinguish three stages in the development of modern civilisation, we recognise the progressive liberation from superstition by scientific knowledge.

When we compare the higher forms of religion of civilised nations we find the same emotional cravings and thought-processes constantly recurring, and the belief in miracles developing in much the same way. The three founders of the great monotheistic Mediterranean religion—Moses, Christ, and Mohammed—were equally regarded as wonder-working prophets, having direct intercourse with God in virtue of their special gifts, and transmitting his commands to men in the shape of laws. The extraordinary authority they enjoy, which has given so much prestige to the religions they founded, is grounded for ordinary people on their miraculous powers—the healing of the sick, the raising of the dead, the expulsion of devils, and so on. If we examine the miracles of Christ as they are given in the Gospels, they run counter to the laws of nature and rational explanation just in the same way as the similar

miracles of Buddha and Brahma in Hindoo mythology, or of Mohammed in the Koran. The same must be said of the belief in the miracle of the bread and wine in the Lord's Supper, and the like. The creed which was probably drawn up by the leaders of the Christian communities of the second century, and received its final and present form in the Church of South Gaul in the fourth and fifth centuries, has been obligatory for Christians for 1,500 years, and recognised by both Church and State as compulsory. This Apostles' Creed was also recognised in Luther's catechism to be fundamental, and is taught in all Protestant and Roman Catholic schools (though not in the Greek Catholic) as the foundation of religious instruction. This extraordinary prestige of the Apostles' Creed, and its great influence on the education of the young, no less than its glaring inconsistency with rational knowledge, compel us to devote a few pages to a critical examination of its three articles.

The first article of the creed deals with creation, and runs: "I believe in God, the Father almighty, Creator of heaven and earth." The modern science of evolution has shown that there never was any such creation, but that the universe is eternal and the law of substance all-ruling. God himself is anthropomorphically conceived as an "Almighty Creator" and the Father of man; heaven (in the sense of the geocentric system) is imagined as a great blue vault spanning the earth. The notion of this "personal God" as an intelligent, immaterial being, creating the material world out of nothing, is wholly irrational and meaningless. That Luther accepted this childish and scientifically worthless idea is clear from his commentary on the first article—"What is that?"

The second article of the creed deals with the dogma

of salvation in the following words: "I believe in Jesus Christ, his only son, our Lord, who was conceived of the Holy Ghost, born of the Virgin Mary, suffered under Pontius Pilate, was crucified, dead, and buried, descended into hell, on the third day rose again from the dead, ascended into heaven, sitteth at the right hand of God, the Father almighty, whence he will come to judge the living and the dead." As these dogmas of the second article contain the chief points of the redemption theory, and are still treasured by millions of educated people, it is necessary to point out their flagrant opposition to pure reason. The chief evil of such creeds is that children, who are yet incapable of reflecting, are forced to learn them by heart. They then remain unchallenged as revealed truths.

The myth of the conception and birth of Jesus Christ is mere fiction, and is at the same stage of superstition as a hundred other myths of other religions. Of the three persons who are mysteriously blended in the triune God, the son Christ is supposed to be begotten by both Father and Holy Ghost, parthenogenetically through the Virgin Mary. I have dealt with the physiology of parthenogenesis in the seventeenth chapter of the *Riddle*. The curious adventures of Christ after his death, the descent into hell, resurrection, and ascension, are also fantastic myths due to the narrow geocentric ideas of an uneducated people. Troelslund has admirably explained the strong influence they have had in his interesting book, *The Idea of Heaven and of the World*.[1] The idea

[1] The English reader may usefully be reminded that Professor Loofs, Haeckel's chief critic, and one of the foremost German theologians, rejects these articles of the creed no less than Haeckel does. A glance at the pertinent articles in the *Encyclopædia Biblica* will show how widely theologians now discard these beliefs.—TRANS.

of the "last judgment," with Christ sitting on the right hand of the Father, as many famous medieval pictures represent (notably Michael Angelo's in the Sistine Chapel at the Vatican), is another outcome of a thoroughly childish and anthropomorphic attitude.

It is remarkable that this second article of the creed says nothing about "redemption," which forms its heading [in Germany]. Luther has dealt with it in his commentary. Christ is believed to have suffered a painful death, like many thousand other martyrs, for his conviction of the truth of his faith and teaching—which reminds one of the more than a hundred thousand men who were done to death by the Inquisition and in the religious wars of the Middle Ages; but not one of the millions of ministers who preach on it every Sunday seems to have shown a rational causal connection of this death with the alleged redemption from sin and death. The whole of this story of redemption has sprung from the primitive, obscure, ethical ideas of uneducated races, especially the crude belief in the propitiatory power of human sacrifice. It has no practical moral value except for those who believe in personal immortality—a scientifically untenable dogma. Whoever builds on this empty promise of a better life beyond may soothe himself with this hope, and reconcile himself to the thousand ills and defects of this world. But the man who studies this life as it really is will not find that the belief in redemption has brought any real improvement. Want and misery and sin are as prevalent as ever; indeed, our modern civilisation has, in many respects, increased them.

The third and last article of the Apostles' Creed runs: "I believe in the Holy Ghost, the holy Catholic Church, the communion of saints, the forgiveness of sins, the resurrection of the body, and life everlasting." In the

curious commentary that Luther made on this article in his catechism, he said that "man cannot believe of his own reason in Jesus Christ"—which is very true—but the Holy Ghost must lead him thereto with his grace; but how the third person of the Trinity effects this enlightenment and sanctification he did not explain. What is meant by the "communion of saints" and the "holy Catholic Church" must be gathered in the light of their history—especially the history of Romanism. This most powerful and still influential section of the Christian Church, which especially claims the title of Catholic and "the one ark of salvation," is really a most pitiful caricature of pure primitive Christianity. It has, with consummate skill, succeeded in preaching the beneficent teaching of Christ in theory and doing just the opposite in practice; we need only recall the Inquisition, the dark history of the Middle Ages, and the political hierarchy which still dominates so much of civilisation.

However, by far the most important clause in the third article is the final expression of belief in "the resurrection of the body and life everlasting." That this greatest "wonder of life" was originally conceived in a purely material form is evident from thousands of pictures in which famous painters have realistically depicted the resurrection of the dead, the aerial flight of the happy souls of the blessed, and the torments of the damned in hell. It is thus conceived still by the majority of believers who take eternal life to be an "enlarged and improved edition" of life here below. This is equally true of Christian and Mohammedan pictures and of the athanatist ideas that prevailed in other religions long before Christ was born, even of the first rudiments of the belief in primitive races. As long as the geocentric theory prevailed, and the heavens were thought to be a

sort of blue glass-bell, illumined by thousands of little stars and the lamp of the sun, arching like a vault over the flat earth, and the fires of hell burned in the cellars below, this barbaric notion of a resurrection of the body and a last judgment could easily be maintained. But its roots were destroyed when Copernicus refuted the geocentric theory in 1545; and athanatism became quite untenable when Darwin shattered the dogma of anthropocentricism. Not only the crude older materialistic idea of eternal life, but also the refined new spiritualistic version, has been rendered untenable by the progress of science in the nineteenth century. I have shown this in the eleventh chapter of the *Riddle*, which closes with the words: "If we take a comprehensive glance at all that modern anthropology, psychology, and cosmology teach with regard to athanatism, we are forced to this definite conclusion. The belief in the immortality of the human soul is in hopeless contradiction with the most solid empirical truths of modern science."[1]

The great influence which has been exercised on civilised nations by the Christian beliefs, supported by the practical exigencies of the State, for thousands of years, was chiefly seen in the crude superstition of the mass of the people. Confessions of faith became as much a matter of routine as the latest fashion in dress or the latest custom, etc. But even the majority of the philosophers were more or less subordinated to the influence. It is true that a few great thinkers freed themselves by the use of pure reason at an early date from the prevalent superstition, and framed systems apart from tradition

[1] Compare the opinion of the distinguished American psychologist, Münsterberg: "Science opposes to any doctrine of individual immortality an unbroken and impregnable barrier" (*Psychology and Life*, p. 85).—TRANS.

and the priests. But most philosophers could not rise to the altitude of these brave Freethinkers; they remained "school-men" in the literal sense, dependent on the dictation of authority, the traditions of the school, and the dogmas of the Church. Philosophy was the "handmaid" of theology and ecclesiasticism. If we examine the history of philosophy in this light, we find in it a struggle for 2,500 years between two great tendencies—the dualism of the majority (with theological and mystic leanings) and the monism of the minority (with rationalistic and naturalistic disposition).

Especially notable are those great Freethinkers of classic antiquity who taught a monistic view of life in the sixth century before Christ—the Ionic natural philosophers, Thales, Anaximander, and Anaximenes; and a little later, Heraclitus, Empedocles, and Democritus. They made the first thorough attempt to explain the world on rational principles, independently of all mythological tradition and theological dogmas. However, these remarkable efforts to found a primitive monism, which found so finished an expression in the *De rerum natura* of the great poet-philosopher, Lucretius Carus (98–54 B.C.), were shortly thrust out by the spread—through Plato's curious dualism—of the belief in the immortality of the soul and the transcendental world of ideas.

The Eleatics, Parmenides and Zeno, had foreshadowed in the fifth century the division of philosophy into two branches; but Plato and his pupil Aristotle (in the fourth century B.C.) succeeded in gaining general acceptance for this dualism and antithesis of physics and metaphysics. Physics devoted itself on the ground of experience to the study of the phenomena of things, leaving their real essences (or noumena) that lay behind the

phenomena to metaphysics. These inner essences are transcendental and inaccessible to empirical research; they form the metaphysical world of eternal ideas, which is independent of the real world, and has its highest unity in God, as the Absolute. The soul, an eternal idea that dwells for a time in the passing human body, is immortal. This consistent dualism of Plato's system, with its sharp antithesis of this world and the next, of body and soul, of world and God, is its chief characteristic. It became all the more influential when Plato's pupil Aristotle blended it with his empirical metaphysics, based on ample scientific experience, and pointed out the idea in the entelechy, or purposively acting principle, of every being; and especially when Christianity (300 years afterwards) found in this dualism a welcome philosophic support of its own transcendental tendency.

In the course of the thousand years which historians call the Middle Ages, and which are usually dated from the fall of the Roman Empire (476) to the discovery of America (1492), the superstition of civilised races reached its highest development. The authority of Aristotle was paramount in philosophy; it was used by the dominant Church for its own purposes. But the influence of the Christian faith, with all the gay colouring which the fairy tales of the Bible added to its structure of dogmas, was seen much more in practical life. In the foreground of belief were the three central dogmas of metaphysics, to which Plato had first given complete expression—the personal God as creator of the world, the immortality of the soul, and the freedom of the human will. As Christianity laid the greatest theoretical stress on the first two dogmas and the greatest practical stress on the third, metaphysical dualism soon prevailed on all sides. Especially inimical

to scientific inquiry was the Christian contempt of nature, and its belittlement of earthly life in view of the eternal life to come. As long as the light of philosophical criticism in any form was extinguished, the flower garden of religious poetry flourished exceedingly and the idea of miracle was taken as self-evident. We know what the practical result of this superstition was from the ghastly history of the Middle Ages, with its Inquisition, religious wars, instruments of torture, and drowning of witches. In the face of the current enthusiasm for the romantic side of medievalism, the Crusades and Church art, we cannot lay too much stress on these dark and bloody pages of its chronicles.

An impartial study of the immense progress made by science in the course of the nineteenth century shows convincingly that the three central metaphysical dogmas established by Plato have become untenable for pure reason. Our clear modern insight into the regularity and causative character of natural processes, and especially our knowledge of the universal reign of the law of substance, are inconsistent with belief in a personal God, the immortality of the soul, and the freedom of the will. If we find this three-fold superstition still widely prevalent, and even retained by academic philosophers as an unshakeable consequence of "critical philosophy," we must trace this remarkable fact chiefly to the great prestige of Immanuel Kant. His so-called critical system—really a hybrid product of the crossing of pure reason with practical superstition—has enjoyed a greater popularity than any other philosophy, and we must stop to consider it for a moment.

I have described in chaps. xiv. and xx. of the *Riddle* the profound opposition between my monistic system and Kant's dualistic philosophy. In the appendix to

the popular edition, especially, I have pointed out the glaring contradictions of his system, which other philosophers have often detected and criticised. Whenever there is question of his teaching one must ask: "Which Kant do you mean? Kant I., the founder of the monistic cosmogony, the critical formulator of pure reason; or Kant II., the author of the dualistic criticism of judgment, the dogmatic discoverer of practical reason?" These contradictions are partly due to the psychological metamorphoses which Kant underwent (*Riddle*, chap. vi.), partly to the perennial conflict between his scientific bias towards a mechanical explanation of this world and his religious craving (an outcome of heredity and education) and mystic belief in a life beyond. This culminates in the distinction between the world of sense and the world of spirit. The sense world (*mundus sensibilis*) lies open to our senses and our intellect, and is empirically knowable within certain limits. But behind it there is the spiritual world (*mundus intelligibilis*), of which we know, and can know, nothing; its existence (as the thing in itself) is, however, assured by our emotional needs. In this transcendental world dwells the power of mysticism.

It is said to be the chief merit of Kant's system that he first clearly stated the problem: "How is knowledge possible?" In trying to solve this problem introspectively, by a subtle analysis of his own mental activity, he reached the conviction that the most important and soundest of all knowledge—namely, mathematical—consists of synthetic *à priori* judgments, and that pure science is only possible on condition that there are strict *à priori* ideas, independent of all experience, without *à posteriori* judgments. Kant regarded this highest faculty of the human mind as innate, and made no

inquiry into its development, its physiological mechanism, and its anatomic organ, the brain. Seeing the very imperfect knowledge which human anatomy had of the complicated structure of the brain at the beginning of the nineteenth century, it was impossible to have at that time a correct idea of its physiological function.

What seems to us to-day to be an innate capacity, or an *à priori* quality, of our phronema, is really a phylogenetic result of a long series of brain-adaptations, formed by *à posteriori* sense-perceptions and experiences.

Kant's much-lauded critical theory of knowledge is therefore just as dogmatic as his idea of "the thing in itself," the unintelligible entity that lurks behind the phenomena. This dogma is erroneously built on the correct idea that our knowledge, obtained through the senses, is imperfect; it extends only so far as the specific energy of the senses and the structure of the phronema admit. But it by no means follows that it is a mere illusion, and least of all that the external world exists only in our ideas. All sound men believe, when they use their senses of touch and space, that the stone they feel fills a certain part of space, and this space does really exist. When all men who can see agree that the sun rises and sets every day, this proves a relative motion of the two heavenly bodies, and so the real existence of time. Space and time are not merely necessary forms of intuition for human knowledge, but real features of things, existing quite independently of perception.

The increasing recognition of fixed natural laws which accompanied the growth of science in the nineteenth century was bound to restrict more and more the blind faith in miracles. There are three chief reasons why we

find this, nevertheless, still so prevalent—the continued influence of dualistic metaphysics, the authority of the Christian Church, and the pressure of the modern State in allying itself with the Church. These three strong bulwarks of superstition are so hostile to pure reason and the truth it seeks that we must devote special attention to them. It is a question of the highest interests of humanity. The struggle against superstition and ignorance is a fight for civilisation. Our modern civilisation will only emerge from it in triumph, and we shall only eliminate the last barbaric features from our social and political life, when the light of true knowledge has driven out the belief in miracles and the prejudices of dualism.

The remarkable history of philosophy in the nineteenth century, which has not yet been written with complete impartiality and knowledge, shows us in the first place an ever-increasing struggle between the rising young sciences and the paramount authority of tradition and dogma. In the first half of the century the various branches of biology made progress without coming into direct collision with natural philosophy. The great advance of comparative anatomy, physiology, embryology, paleontology, the cell-theory, and classification, provided scientists with such ample material that they attached little importance to speculative metaphysics. It was otherwise in the second half of the nineteenth century. Soon after its commencement the controversy about the immortality of the soul broke out, in which Moleschott (1852), Büchner, and Carl Vogt (1854) contended for the physiological dependence of the soul on the brain, while Rudolph Wagner endeavoured to maintain the prevailing metaphysical idea of its supernatural character. Then Darwin especially initiated in 1859 that vast reform

in biology which brought to light the natural origin of species and shattered the miracle of creation. When the application to man of the theory of descent and the biogenetic law was made by anthropogeny (1874), and his evolution from a series of other mammals was proved, the belief in the immortality of the soul, the freedom of the will, and an anthropomorphic deity lost its last support. Nevertheless, these three fundamental dogmas continued to find favour in academic philosophy, which mainly followed the paths opened out by Kant. Most of the representatives of philosophy at the universities are narrow metaphysicians and idealists, who think more of the fiction of the "intelligible world" than of the truth of the world of sense. They ignore the vast progress made by modern biology, especially in the science of evolution; and they endeavour to meet the difficulties which it creates for their transcendental idealism by a sort of verbal gymnastic and sophistry. Behind all these metaphysical struggles there is still the personal element —the desire to save one's immortality from the wreck. In this it comes into line with the prevailing theology, which again builds on Kant. The pitiful condition of modern psychology is a characteristic result of this state of things. While the empirical physiology and pathology of the brain have made the greatest discoveries, the comparative anatomy and histology of the brain have thrown light on the details of its elaborate structure, and the ontogeny and phylogeny of the brain have proved its natural origin, the speculative philosophy of the schools stands aside from it all, and in its introspective analysis of the functions of the brain will not hear a word about the brain itself. It would explain the working of a most complicated machine without paying any attention to its structure. It is, therefore, not surprising to find that

the dualistic theories established by Kant flourish at our universities as they did in the Middle Ages.

If the official philosophers, whose formal duty it is to study truth and natural law, still cling to the belief in miracles in spite of all the advance of empirical science, we shall not be surprised to find this in the case of official theology. Nevertheless, the sense of truth has prompted many unprejudiced and honourable theologians to look critically at the venerable structure of dogma, and open their minds to the streaming light of modern science. In the first third of the nineteenth century a rationalistic section of the Protestant Church attempted to rid itself of the fetters of dogma and reconcile its ideas with pure reason. Its chief leader, Schleiermacher, of Berlin, though an admirer of Plato and his dualist metaphysics, approached very close to modern pantheism. Subsequent rationalistic theologians, especially those of the Tübingen school (Baur, Zeller, etc.), devoted themselves to the historical study of the Gospels and their sources and development, and thus more and more destroyed the base of Christian superstition. Finally, the radical criticism of David Friedrich Strauss showed, in his *Life of Jesus* (1835), the mythological character of the whole Christian system. In his famous work, *The Old and New Faith* (1872), this honourable and gifted theologian finally abandoned the belief in miracles, and turned to natural knowledge and the monistic philosophy for the construction of a rational view of life on the basis of critical experience. This work has lately been continued by Albert Kalthoff. Moreover, many modern theologians (such as Savage, Nippold, Pfleiderer, and other liberal Protestants) have endeavoured in various ways to obtain a certain recognition for the claims of progressive science, and reconcile

them with theology, while discarding the belief in the miraculous. However, these rationalistic efforts, based on monistic or pantheistic views, are still isolated and apparently without effect. The great majority of modern theologians adhere to the traditional teaching of the Church, whose columns and windows are still everywhere adorned with miracles. While a few liberal Protestants restrict their faith to the three fundamental dogmas, most of them still believe in the myths and legends which fill the pages of the Gospels. This orthodoxy is, moreover, encouraged of late by the conservative and reactionary attitude taken up by many Governments on political grounds.

Most modern Governments maintain the connection with the Church in the idea that the traditional belief in the miraculous is the best security for their own continuance. Throne and altar must protect and support each other. However, this conservative-Christian policy meets two obstacles in an increasing measure. On the one hand, the ecclesiastical hierarchy is always trying to set its spiritual power above the secular and make the State serve its own purposes; and, on the other hand, the modern right of popular representation affords an opportunity to make the voice of reason heard and oppose the reactionary conservatives with opportune reforms. The chief rulers and the ministers of public instruction, who have a great influence in this struggle, generally favour the teaching of the Church, not out of conviction of its truth, but because they think knowledge brings unrest, and because docile and ignorant subjects are easier to rule than educated and independent citizens. Hence it is that we now hear so much on every occasion, in speeches from the throne and at banquets, at the opening of churches and the unveiling

of monuments, from able and influential speakers, of the value of faith. They would give the palm to faith in its struggle with knowledge. Thus we get this paradoxical situation in educated countries (such as Prussia), that encouragement is given at once to modern science and technical training and to the orthodox Church, which is its deadly enemy. As a rule, it is not stated in these florid orations to how many and what kind of miracles this precious faith must extend. Nevertheless we may yet, in view of the spread of intellectual reaction in Germany, see it made obligatory for at least all priests, teachers, and other servants of the State to profess a belief in the three fundamental mysteries—the triune God of the catechism, the personal immortality of the soul, and the absolute freedom of the human will—and even in many of the other miracles which are found in the Gospels, sacred legends, and religious journals of our time.

The refined belief in the miraculous embodied in Kant's practical philosophy assumed many different forms among his followers, the Neo-Kantians, approaching sometimes more and sometimes less to the conventional beliefs. Through a long series of variations, which still continue to develop, it is gradually passing into the cruder form of superstition which we find popular to-day as spiritism, and which provides the basis for what is called occultism. Kant himself, in spite of his subtle and clear critical faculty, had a decided leaning to mysticism and positive dogmatism, which showed itself especially in his later years. He thought a good deal of Swedenborg's idea of the spirit world forming a universe apart, and compared this to his *mundus intelligibilis*. Among the natural philosophers of the first half of the nineteenth century Schelling (in

his later writings), Schubert (in his *History of the Soul* and *Observations on the Dark Side of Science*), and Perty (in his mystic anthropology) especially investigated the mysterious phenomena of mental action, and sought to connect them with the physiological functions of the brain on the one hand and supernatural spiritual agencies on the other. Modern spook-seeking has no more value than medieval magic, cabbalism, astrology, necromancy, dream-interpretation, and invocation of the devil.

We must put at the same stage of superstition the spiritism and occultism we find mentioned so much in modern literature. There are always thousands of credulous folk in educated countries who are taken in by the performances of the spiritists and their media, and are ready to believe the unbelievable. Spirit-rapping, table-turning, spirit-writing, the materialisation and photographing of deceased souls, find credit, not only among the uneducated masses, but even among the most cultured, and sometimes among imaginative scientists. It has been proved without avail by numbers of impartial observations and experiments that these occultist performances depend partly on conscious fraud and partly on careless self-deception. *Mundus vult decipi*—"the world wishes to be taken in"—as the old saying has it. This spiritistic fraud is particularly dangerous when it clothes itself with the mantle of science, makes use of the physiological phenomena of hypnotism, and even assumes a monistic character. Thus, for instance, one of the best-known occultist writers, Karl du Prel, has written, not only a *Philosophy of Mysticism and Studies of Scientific Subjects*, but also (1888) a *Monistic Psychology*, which is dualistic from beginning to end. In these popular writings lively imagination and brilliant presentation are

combined with a most flagrant lack of critical sense and of knowledge of the elements of biology (*cf.* chap. xvi. of the *Riddle*). It seems that the hereditary bias towards mysticism and superstition is not yet eliminated even from the educated mind of our time. It is to be explained phylogenetically by inheritance from pre-historic barbarians and savages, in whom the earliest religious ideas were wholly dominated by animism and fetichism.

## Chapter IV.

# THE SCIENCE OF LIFE

Object of biology. Relation to the other sciences. General and special biology. Natural philosophy. Monism: hylozoism, materialism, dynamism. Naturalism. Nature and spirit. Physics. Metaphysics. Dualism. Freedom and natural law. God in biology. Realism. Idealism. Branches of biology. Morphology and physiology. Anatomy and biogeny. Ergology and perilogy.

The broad realm of science has been vastly extended in the course of the nineteenth century. Many new branches have established themselves independently; many new and most fruitful methods of research have been discovered, and have been applied with the greatest practical success in furthering the advance of modern thought. But this enormous expansion of the field of knowledge has its disadvantages. The extensive division of labour it has involved has led to the growth of a narrow specialism in many small sections; and in this way the natural connection of the various provinces of knowledge, and their relation to the comprehensive whole, have been partly or wholly lost sight of. The importation of new terms which are used in different senses by one-sided workers in the various fields of science has caused a good deal of misunderstanding and confusion. The vast structure of science tends more and more to become a tower of Babel, in the labyrinthic passages of which few are at their ease and few any longer understand the language of other workers. In these circumstances, it

seems advisable, at the commencement of our philosophic study of "the wonders of life," to form a clear idea of our task. We must carefully define the place of biology among the sciences, and the relation of its various branches to each other and to the different systems of philosophy.

In the broadest sense in which we can take it, biology is the whole study of organisms or living beings. Hence not only botany (the science of plants) and zoology (the science of animals), but also anthropology (the science of man), fall within its domain. We then contrast with it all the sciences which deal with inorganic or lifeless bodies, which we may collectively call abiology (or anorganology); to this belong astronomy, geology, mineralogy, hydrology, etc. This division of the two great branches of science does not seem difficult in view of the fact that the idea of life is sharply defined physiologically by its metabolism and chemically by its plasm; but when we come to study the question of abiogenesis (chap. xv.) we shall find that this division is not absolute, and that organic life has been evolved from inorganic nature. Moreover, biology and abiology are connected branches of cosmology, or the science of the world.

While the idea of biology is now usually taken in this broad sense in most scientific works and made to embrace the whole of living nature, we often find (especially in Germany) a narrower application of the term. Many authors (mostly physiologists) understand by it a section of physiology—namely, the science of the relations of living organisms to the external world, their habitat, customs, enemies, parasites, etc. I proposed long ago to call this special part of biology œcology (the science of home-relations), or bionomy. Twenty years later others

suggested the name of ethology. To call this special study any longer biology in the narrower sense is very undesirable, because it is the only name we have for the totality of the organic sciences.

Like every other science, biology has a general and a special part. General biology contains general information about living nature; this is the subject of the present study of the wonders of life. We might also describe it as biological philosophy, since the aim of true philosophy must be the comprehensive survey and rational interpretation of all the general results of scientific research. The innumerable discoveries of detailed facts which observation and experiment give us, and which are combined into a general view of life in philosophy, form the subject of empirical science. As the latter, on the side of the organic world, or as empirical biology, forms the first object of the science of life, and seeks to effect in the system of nature a logical arrangement and summary grouping of the countless special forms of life, this special biology is often wrongly called the science of classification.

The first comprehensive attempt to reduce to order and unity the ample biological material which systematic research had accumulated in the eighteenth century was made by what we call "the older natural philosophy" at the beginning of the nineteenth century. Reinhold Treviranus (of Bremen) had made a suggestive effort to accomplish this difficult task on monistic principles in his *Biology, or Philosophy of Living Nature* (1802). Special importance attaches to the year 1809, in which Jean Lamarck (of Paris) published his *Philosophie Zoologique*, and Lorentz Oken (of Jena) his *Manual of Natural Philosophy*. I have fully appreciated the service of Lamarck, the founder of the theory of descent, in my

earlier writings. I have also recognised the great merit of Lorentz Oken, who not only aroused a very wide interest in this science by his *General Natural History*, but also put forward some general observations of great value. His "infamous" theory of a primitive slime, and the development of infusoria out of it, is merely the fundamental idea of the theory of protoplasm and the cell which was long afterwards fully recognised. These and other services of the older natural philosophy were partly ignored and partly overlooked, because they went far beyond the scientific horizon of the time, and their authors to an extent lost themselves in airy and fantastic speculations. The more scientists confined themselves in the following half-century to empirical work and the observation and description of separate facts, the more it became the fashion to look down on all "natural philosophy." The most paradoxical feature of the situation was that purely speculative philosophy and idealist metaphysics had a great run at the same time, and their castles in the air, utterly destitute of biological foundation, were much admired.

The magnificent reform of biology which Darwin initiated in 1859 by his epoch-making *Origin of Species* gave a fresh impulse to natural philosophy. As this work not only used the rich collection of facts already made in proof of the theory of descent, but gave it a new foundation in the theory of selection (Darwinism properly so-called), everything seemed to call for the embodiment of the new conception of nature in a monistic system. I made the first effort to do this in my *General Morphology* (1866). As this found few supporters among my colleagues, I undertook in my *History of Creation* (1868) to make the chief points of the system accessible to the general reader. The remarkable

success of this book (a tenth edition of it appearing in 1902) emboldened me at the end of the nineteenth century to state the general principles of my monistic philosophy in my *Riddle of the Universe*. About the same time (1899) there appeared the work of the Kiel botanist, Johannes Reinke, *The World as Reality;* and two years afterwards he followed it up with a supplementary volume, *Introduction to Theoretic Biology*. As Reinke treats the general problems of natural philosophy from a purely mystic and dualistic point of view, his ideas are diametrically opposed to my monistic and naturalistic principles.

The history of philosophy describes for us the infinite variety of ideas that men have formulated during the last 3,000 years on the nature of the world and its phenomena. Uberweg has given us, in his excellent *History of Philosophy*, a thorough and impartial account of these various systems. Fritz Schultze has published a clear and compendious "tabulated outline" of them in thirty tables in his genealogical tree of philosophy, and at the same time shown the phylogeny of ideas. When we survey this enormous mass of philosophic systems from the point of view of general biology, we find that we can divide them into two main groups. The first and smaller group contains the monistic philosophy, which traces all the phenomena of existence to one single common principle. The second and larger group, to which most philosophic systems belong, constitutes the dualistic philosophy, according to which there are two totally distinct principles in the universe. These are sometimes expressed as God and the world, sometimes as the spiritual world and material world, sometimes as mind and matter, and so on. In my opinion, this antithesis of monism and dualism is the most important in the whole history of philosophy. All

other systems are only variations of one or the other of these, or a more or less obscure combination of the two.

The form of monism which I take to be the most complete expression of the general truth, and which I have advocated in my writings for thirty-eight years, is now generally called hylozoism. This expresses the fact that all substance has two fundamental attributes; as matter *(hyle)* it occupies space, and as force or energy it is endowed with sensation (*cf.* chap. xix.). Spinoza, who gave the most perfect expression to this idea in his "philosophy of identity," and most clearly treated the notion of substance (as the all-embracing essence of the world), clothes it with two general attributes—extension and thought. Extension is identical with real space, and thought with (unconscious) sensation. The latter must not be confused with conscious human thought; intelligence is not found in substance, but is a special property of the higher animals and man. Spinoza identifies his substance with nature and God, and his system is accordingly called pantheism; but it must be understood that he rejects the anthropomorphic, personal idea of deity.

A good deal of the infinite confusion that characterises the conflicts of philosophers over their systems is due to the obscurity and ambiguity of many of their fundamental ideas. The words "substance" and "God," "soul" and "spirit," "sensation" and "matter," are used in the most different and changing senses. This is especially true of the word "materialism," which is often wrongly taken to be synonymous with monism. The moral bias of idealism against *practical* materialism (or pure selfishness and sensualism) is forthwith transferred to theoretical materialism, which has nothing to do with it; and the strictures which are justly urged against the one are most unjustifiably applied to the

other. Hence it is important to distinguish very carefully between these two meanings of materialism.

Theoretical materialism (or hylonism), as a realistic and monistic philosophy, is right in so far as it conceives matter and force to be inseparably connected, and denies the existence of immaterial forces. But it is wrong when it denies all sensation to matter, and regards actual energy as a function of dead matter. Thus, in ancient times Democritus and Lucretius traced all phenomena to the movements of dead atoms, as did also Holbach and Lamettrie in the eighteenth century. This view is held to-day by most chemists and physicists. They regard gravitation and chemical affinity as a mere mechanical movement of atoms, and this, in turn, as the general source of all phenomena; but they will not allow that these movements necessarily pre-suppose a kind of (unconscious) sensation. In conversation with distinguished physicists and chemists I have often found that they will not hear a word about a "soul" in the atom. In my opinion, however, this must necessarily be assumed to explain the simplest physical and chemical processes. Naturally I am not thinking of anything like the elaborate psychic action of man and the higher animals, which is often bound up with consciousness; we must rather descend the long scale of the development of consciousness until we reach the simplest protists, the monera (chap. ix.). The psychic activity of these homogeneous particles of plasm (for instance, the chromacea) rises very little above that of crystals; as in the chemical synthesis in the moneron, so in crystallisation we are bound to assume that there is a low degree of sensation (not of consciousness), in order to explain the orderly arrangement of the moving molecules in a definite structure.

The prejudice against theoretical materialism (or materialistic monism) which still prevails so much is partly due to its rejection of the three central dogmas of dualist metaphysics, and partly to a confusion of it with hedonism. This practical materialism in its extreme forms (as Aristippus of Cyrene and the Cyrenaic school, and afterwards Epicurus, taught it) finds the chief end of life in pleasure—at one time crude sensual pleasure, and at others spiritual pleasure. Up to a certain point, this thirst for happiness and a pleasant and enjoyable life is innate in every man and higher animal, and so far just; it only began to be censured as sinful when Christianity directed the thoughts of men to eternal life, and taught them that their life on earth was only a preparation for the future. We shall see afterwards, when we come to weigh the value of life (chap. xvii.), that this asceticism is unjustifiable and unnatural. But as every legitimate enjoyment can become wrong by excess, and every virtue be turned into vice, so a narrow hedonism is to be condemned, especially when it allies itself with egoism. However, we must point out that this excessive thirst for pleasure is in no way connected with materialism, but is often found among idealists. Many convinced supporters of theoretical materialism (many scientists and physicians, for instance) lead very simple, blameless lives, and are little disposed to material pleasures. On the other hand, many priests, theologians, and idealist philosophers, who preach theoretical idealism, are pronounced hedonists in practice. In olden times many temples served at one and the same time for the theoretic worship of the gods and for practical excesses in the way of wine and love; and even in our day the luxurious and often vicious lives of the higher clergy (at Rome, for instance) do not fall

far short of the ancient models. This paradoxical situation is due to the special attractiveness of everything that is forbidden. But it is utterly unjust to extend the natural feeling against excessive and egoistic hedonism to theoretical materialism and to monism. Equally unjust is the habit, still widely spread, of depreciating matter, as such, in favour of spirit. Impartial biology has taught us of late years that what we call "spirit" is—as Goethe said long ago—inseparably bound up with matter. Experience has never yet discovered any spirit apart from matter.

On the other hand, pure dynamism, now often called energism (and often spiritualism), is just as one-sided as pure materialism. Just as the latter takes one attribute of substance, matter, as the one chief cause of phenomena, dynamism takes its second attribute, force *(dynamis)*. Leibnitz most consistently developed this system among the older German philosophers; and Fechner and Zöllner have recently adopted it in part. The latest development of it is found in Wilhelm Ostwald's *Natural Philosophy* (1902). This work is purely monistic, and very ingeniously endeavours to show that the same forces are at work in the whole of nature, organic and inorganic, and that these may all be comprised under the general head of energy. It is especially satisfactory that Ostwald has traced the highest functions of the human mind (consciousness, thought, feeling, and will), as well as the simplest physical and chemical processes (heat, electricity, chemical affinity, etc.), to special forms of energy, or natural force. However, he is wrong when he supposes that his energism is an entirely new system. The chief points of it are found in Leibnitz; and other Leipzig scientists, especially Fechner and Zöllner, had come very close to similar

spiritualistic views—the latter going into outright spiritism. Ostwald's chief mistake is to take the terms "energy" and "substance" to be synonymous. Certainly his universal, all-creating energy is, in the main, the same as the substance of Spinoza, which we have also adopted in our "law of substance." But Ostwald would deprive substance of the attribute of matter altogether, and boasts of his *Refutation of Materialism* (1895). He would leave it only the one attribute, energy, and reduce all matter to immaterial points of force. Nevertheless, as chemist and physicist, he never gets rid of space-filling substance—which is all we mean by "matter"—and has to treat it and its parts, the physical molecules and chemical atoms (even if only conceived as symbols), daily as "vehicles of energy." Ostwald would reject even these in his pursuit of the illusion of a "science without hypotheses." As a fact, he is forced every day, like every other exact scientist, to assume and apply in practice the indispensable idea of matter, and its separate particles, the molecules and atoms. Knowledge is impossible without hypotheses.

Monism is best expressed as hylozoism, in so far as this removes the antithesis of materialism and spiritualism (or mechanicism and dynamism), and unites them in a natural and harmonious system. Our monistic system has been charged with leading to pure naturalism; one of its most vehement critics, Frederick Paulsen, attaches so much importance to this stricture that he thinks it as dangerous as dogmatic clericalism. We may, therefore, usefully consider the idea of naturalism, and point out in what sense we accept it and identify it with monism. The key to the position is in our monistic anthropogeny, our unprejudiced conviction, supported by every branch of anthropological research, of "man's place in nature,"

as we have established it in the first section of the *Riddle* (chaps. ii.–v.). Man is a purely natural being, a placental mammal of the order of primates. He was phylogenetically evolved in the course of the tertiary period from a series of the lower primates (directly from the anthropoid apes, but earlier from the cynocephali and lemures). Savage man, as we have him to-day in the Veddah or Australian negro, is physiologically nearer to the apes than to highly-civilised men.

Anthropology (in the widest sense) is only a particular branch of zoology, to which we must assign a special position on account of its extreme importance. Hence all the sciences which relate to man and his psychic activity—especially what are called the moral sciences—must be regarded from our monistic point of view as special branches of zoology and as natural sciences. Human psychology is inseparably connected with comparative animal psychology, and this again with that of the plants and protists. Philology studies in human speech a complicated natural phenomenon, which depends on the combined action of the brain-cells of the phronema, the muscles of the tongue, and the vocal cords of the larynx, as much as the cry of mammals and the song of birds do. The history of mankind (which we, in our curious anthropocentric mood, call the history of the world), and its highest branch, the history of civilisation, is connected by modern pre-historic science directly with the stem-history of the primates and the other mammals, and indirectly with the phylogeny of the lower vertebrates. Hence, when we consider the subject without prejudice, we do not find a single branch of human science that passes the limits of natural science (in the broadest sense), any more than we find Nature herself to be supernatural.

Just as monism, or naturalism, embraces the totality

of science, so on our principles the idea of nature comprises the whole scientifically knowable world. In the strict monistic sense of Spinoza the ideas of God and Nature are synonymous for us. Whether there is a realm of the supernatural and spiritual beyond nature we do not know. All that is said of it in religious myths and legends, or metaphysical speculations and dogmas, is mere poetry and an outcome of imagination. The imagination of civilised man is ever seeking to produce unified images in art and science, and when it meets with gaps in these in the association of ideas it endeavours to fill them with its own creations. These creations of the phronema with which we fill the gaps in our knowledge are called *hypotheses* when they are in harmony with the empirically established facts, and *myths* when they contradict the facts: this is the case with religious myths, miracles, etc. Even when people contrast mind with nature this is only a result, as a rule, of similar superstitions (animism, spiritism, etc.). But when we speak of man's mind as a higher psychic function, we mean a special physiological function of the brain, or that particular part of the cortex of the brain which we call the phronema, or organ of thought. This higher psychic function is a natural phenomenon, subject, like all other natural phenomena, to the law of substance. The old Latin word *natura* (from *nasci*, to be born) stands, like the corresponding Greek term *physis* (from *phyo*—to grow), for the essence of the world as an eternal "being and becoming"—a profound thought! Hence physics, the science of the *physis*, is, in the broadest sense of the word, "natural science."

The extensive division of labour which has taken place in science, on account of the enormous growth of our knowledge in the nineteenth century and the rise of

many new disciplines, has very much altered their relations to each other and to the whole, and has even given a fresh meaning and connotation to the term. Hence by physics, as it is now taught at the universities, is usually understood only that part of inorganic science which deals with the molecular relations of substance and the mechanism of mass and ether, without regard to the qualitative differences of the elements, which are expressed in the atomic weight of their smallest particles, the atoms. The study of the atoms and their affinities and combinations belongs to chemistry. As this province is very extensive and has its special methods of research, it is usually put side by side with physics as of equal importance; in reality, however, it is only a branch of physics—chemistry is the physics of the atoms. Hence, when we speak of a physico-chemical inquiry or phenomenon, we might justly describe it briefly as *physical* (in the wider sense). Physiology, again, a particularly important branch of it, is in this sense the physics of living things, or the physico-chemical study of the living body.

Since Aristotle dealt with the eternal phenomena of nature in the first part of his works, and called this *physics*, and with their inner nature in the second part, to which he gave the name of *metaphysics*, the two terms have undergone many and considerable modifications. If we restrict the term "physics" to the empirical study of phenomena (by observation and experiment), we may give the name of metaphysics to every hypothesis and theory that is introduced to fill up the gaps in it. In this sense the indispensable theories of physics (such as the assumption that matter is made up of molecules and atoms and electrons) may be described as metaphysical; such also is our assumption that all substance is endowed

with sensation as well as extension (matter). This monistic metaphysics, which recognises the absolute dominion of the law of substance in all phenomena, but confines itself to the study of nature and abandons inquiry into the supernatural, is, with all its theories and hypotheses, an indispensable part of any rational philosophy of life. To claim, as Ostwald does, that science must be free from hypotheses is to deprive it of its foundations. But it is very different with the current dualistic metaphysics, which holds that there are two distinct worlds, and which we find in a hundred forms as philosophic dualism.

If we understand by metaphysics the science of the ultimate ground of things, springing from the rational demand for causes, it can only be regarded, from the physiological point of view, as a higher and late-developed function of the phronema. It could only arise with the complete development of the brain in civilised man. It is completely lacking among savages, whose organ of thought rises very little above that of the most intelligent animals. The laws of the psychic life of the savage have been closely studied by modern ethnology. It teaches us that the higher reason is not found in savages, and that their power of abstract thought and of forming concepts is at a very low level. Thus, for instance, the Veddahs, who live in the forests of Ceylon, have not the general idea of trees, though they know and give names to individual trees. Many savages cannot count up to five ; they never reflect on the ground of their existence or think of the past or future. Hence it is a great error for Schopenhauer and other philosophers to define man as a "metaphysical animal," and to seek a profound distinction between man and the animal in the need for a metaphysic. This craving has only been awakened

and developed by the progress of civilisation. But even in civilised communities it (like consciousness) is not found in early youth, and only gradually emerges. The child has to learn to speak and think. In harmony with our biogenetic law, the child reproduces in the various stages of its mental development the whole of the gradations which lead from the savage to the barbarian, and from the barbarian to the half-civilised, and on to the fully-educated man. If this historical development of the higher human faculties had always been properly appreciated, and psychology had been faithful to the comparative and genetic methods, many of the errors of the current metaphysical systems would have been avoided. Kant would not then have produced his theory of *à priori* knowledge, but would have seen that all that now seems to be *à priori* in civilised man was originally acquired by *à posteriori* experiences in the long evolution of civilisation and science. Here we have the root of the errors which are distinctive of dualism and the prevailing metaphysical transcendentalism.

Like all science, biology is *realistic*—that is to say, it regards its object, the organisms, as really existing things, the features of which are to an extent knowable through our senses *(sensorium)* and organ of thought *(phronema)*. At the same time, we know that these cognitive organs, and the knowledge they bring us, are imperfect, and that there may be other features of organisms that lie beyond our means of perception altogether. But it by no means follows from this that, as our idealist opponents say, the organisms (and all other things) exist only in our mind (in the images in our cortex). Our pure monism (or hylozoism) agrees with realism in recognising the unity of being of each organism, and denying that there is any essential

distinction between its knowable phenomenon and its internal hidden essence (or noumenon), whether the latter be called, with Plato, the eternal "idea," or, with Kant, the "thing in itself." Realism is not identical with materialism, and may even be definitely connected with the very opposite, dynamism or energism.

As realism generally coincides with monism, so idealism is usually identical with dualism. The two most influential representatives of dualism, Plato and Kant, said that there were two totally distinct worlds. Nature, or the empirical world, is alone accessible to our experience, while the spiritual or transcendental world is not. The existence of the latter is known to us only by the emotions or by practical reason; but we can have no idea of its nature. The chief error of this theoretical idealism is the assumption that the soul is a peculiar, immaterial being, immortal and endowed with *à priori* knowledge. The physiology and ontogeny of the brain (together with the comparative anatomy and histology of the phronema) prove that the soul of man is, like that of all other vertebrates, a function of the brain, and inseparably bound up with this organ. Hence this idealist theory of knowledge is just as inconsistent with realistic biology as is the psycho-physical parallelism of Wundt or the psycho-monism of more recent physiologists, which in the end issues in a complete dualism of body and mind. It is otherwise with *practical* idealism. When this presents the symbols or ideals of a personal God, an immortal soul, and the free-will as ethical stimuli, and uses them for their pædogogical worth in the education of the young, it may have a good influence for a time, which is independent of their theoretical untenability.

The many branches of biology which have been

developed independently in the course of the nineteenth century ought to remain in touch with each other, and co-operate with a clear apprehension of their task, if they are to attain their high purpose of framing a unified science embracing the whole field of organic life. Unfortunately, this common aim is often lost sight of in the specialisation of study; the philosophical task is neglected in favour of the empirical. The confusion that has ensued makes it desirable to determine the mutual positions of the various biological disciplines. I went into this somewhat fully in my academic speech on the development and aim of zoology in 1869. But as this essay is little known, I will briefly resume the chief points of it.

In correspondence with the long-established distinction between the plant and the animal, the two chief branches of biology, zoology and botany, have developed side by side, and are represented by two different chairs in the universities. Independently of these, there arose at the very beginning of scientific activity that field of inquiry which deals with human life in all its aspects—the anthropological disciplines and the so-called "mental sciences" (history, philology, psychology, etc.). Since the theory of descent has proved man's origin from vertebrate ancestors, and thus anthropology has been recognised as a part of zoology, we have begun to understand the inner historic connection between these various branches of anthropology, and to combine them in a comprehensive science of man. The immense extent and the great importance of this science have justified the creation of late years of special chairs of anthropology. It seems desirable to do the same for the science of the protists, or unicellular organisms. The cell theory, or cytology, as an elementary part of

anatomy, has to be dealt with in both botany and zoology; but the lowest unicellular representatives of both kingdoms, the primitive plants (protophyta) and the primitive animals (protozoa), are so intimately connected, and throw so great a light, as independent rudimentary organisms, on the tissue cells in the *histon*, or multicellular organism, that we must regard as a sign of progress the recent proposal of Schaudinn to found a special institute and journal for the science of protists. One very important section of it is bacteriology.

The practical division of biology, according to the extent of the organic kingdom, leads us to mark out four chief provinces of research: protistology (the science of the unicellulars), botany (the science of plants), zoology (the science of animals), and anthropology (the science of man). In each of these four fields we may then distinguish morphology (the science of forms) and physiology (the science of functions) as the two chief divisions of scientific work. The special methods and means of observation differ entirely in the two sections. In morphology the work of description and comparison is the most important as regards both outer form and inner structure. In physiology the exact methods of physics and chemistry are especially demanded—the observation of vital activities and the attempt to discover the physical laws that govern them. As a correct knowledge of human anatomy and physiology is indispensable for scientific medicine, and the work requires a particularly large apparatus, these two sciences have long been studied separately, and have been handed over to the medical faculty in the division of the academic curriculum.

The broad field of morphology may be divided into anatomy and biogeny; the one deals with the fully

developed, and the other with the developing, organism. Anatomy, the study of the formed organism, studies both the external form and the inner structure. We may distinguish as its two branches the science of structures (tectology) and the science of fundamental forms (promorphology). Tectology investigates the features of the structure in the organic *individual*, and the composition of the body out of various parts (cells, tissues, and organs). Promorphology describes the real form of these individual parts and of the whole body, and endeavours to reduce them mathematically to certain fundamental forms (chap. viii.). Biogeny, or the science of the evolution of organisms, is also divided into two parts—the science of the individual (ontogeny) and of the stem or species (phylogeny); each follows its own peculiar methods and aims, but they are most intimately connected by the biogenetic law. Ontogeny deals with the development of the individual organism from the beginning of its existence to death; as embryology it observes the growth of the individual within the foetal membranes; and as metamorphology (or the science of metamorphoses) it follows the subsequent changes in post-foetal life (chap. xvi.). The task of phylogeny is to trace the evolution of the organic stem or species—that is to say, of the chief divisions in the animal and plant worlds, which we describe as classes, orders, etc.; in other words, it traces the genealogy of species. It relies on the facts of paleontology, and fills up the gaps in this by comparative anatomy and ontogeny.

The science of the vital phenomena, which we call physiology, is for the most part the physiology of work, or ergology; it investigates the functions of the living organism, and has to reduce them as closely as possible to physical and chemical laws. Vegetable ergology deals

with what are called the vegetative functions, nutrition and reproduction; animal ergology studies the animal activities of movement and sensation. Psychology is directly connected with the latter. But the study of the relations of the organism to its environment, organic and inorganic, also belongs to physiology in the wider sense; we call this part of it perilogy, or the physiology of relations. To this belong chorology, or the science of distribution (also called biological geography, as it deals with geographical and topographical distribution), and œcology or bionomy (also recently called ethology), the science of the domestic side of organic life, of the life-needs of organisms and their relations to other organisms with which they live (biocenosis, symbiosis, parasitism).

## Third Table.

### SYNOPSIS OF THE CHIEF BRANCHES OF BIOLOGY (1869).

Biology = The Science of Life.

I. Protistology = the science of single cells—unicellular organisms.
II. Botany = the science of plants—tissue plants (metaphyta).
III. Zoology = the science of animals—tissue animals (metazoa).
IV. Anthropology = the science of man—speaking primates.

} The four chief branches of systematic biology.

| A. Morphology = The Science of Forms. Anatomy and biogeny of organisms. | | B. Physiology = The Science of Functions. Physics and chemistry of the organism. | |
|---|---|---|---|
| A I. Anatomy.<br>The science of structure.<br>1. Tectology.<br>The science of structure.<br>Cytology, science of cells.<br>Histology, science of tissues.<br>Organology, science of organs.<br>Blastology, science of persons.<br>Kormology, science of trunks.<br>2. Promorphology.<br>The science of fundamental forms. Knowledge of the geometrical ideal forms (mathematically definable) in relation to the concrete real form of the individual. | A II. Biogeny.<br>The science of development.<br>3. Phylogeny.<br>Stem history.<br>Paleontology and genealogy.<br>Transformism or theory of descent. Natural classification.<br>4. Ontogeny.<br>4*a*. Embryology.<br>(Development within the fœtal membranes.)<br>4*b*. Metamorphology.<br>(Modifications of the organism after fœtal life.) | B I. Ergology.<br>Physiology of work.<br>5. Vegetal ergology.<br>Physiology of the vegetative functions.<br>5*a*. Trophonomy.<br>The science of metabolism.<br>5*b*. Gonimatology.<br>The science of reproduction.<br>6. Animal ergology.<br>6*a*. Phoronomy.<br>The science of movement.<br>6*b*. Sensonomy.<br>The science of sensation.<br>6*c*. Psychology. | B II. Perilogy.<br>Physiology of relations.<br>7. Chorology.<br>The science of distribution.<br>Biological geography and topography.<br>The science of migrations.<br>8. Œcology<br>(or bionomy, or ethology).<br>The science of domestic life.<br>Biological economy.<br>Relations of the organism to the environment, and to other organisms with which it lives. |

## Chapter V.

# DEATH

Life and death. Individual death. Immortality of the unicellulars. Death of the protists and tissue-organisms. Causes of physiological death. Using up of the plasma. Regeneration. Biotonus. Perigenesis of the plastidules: memory of the biogens. Regeneration of protists and tissue-organisms. Senile debility. Disease. Necrobiosis. The lot of death. Providence. Chance and fate. Eternal life. Optimism and pessimism. Suicide and self-redemption. Redemption from evil. Medicine and philosophy. Maintenance of life. Spartan selection.

Nothing is constant but change! All existence is a perpetual flux of "being and becoming"! That is the broad lesson of the evolution of the world, taken as a whole or in its various parts. Substance alone is eternal and unchangeable, whether we call this all-embracing world-being Nature, or Cosmos, or God, or World-spirit. The law of substance teaches us that it reveals itself to us in an infinite variety of forms, but that its essential attributes, matter and energy, are constant. All individual forms of substance are doomed to destruction. That will be the fate of the sun and its encircling planets, and of the organisms that now people the earth —the fate of the bacterium and of man. Just as the existence of every organic individual had a beginning, it will also undeniably have an end. Life and death are irrevocably united. However, philosophers and biologists hold very different views as to the real causes of this destiny. Most of their opinions are at once out of

court, because they have not a clear idea of the nature of life, and so can have no adequate idea of its termination —death.

The inquiry into the nature of organic life which we instituted in the second chapter has shown us that it is, in the ultimate analysis, a chemical process. The "miracle of life" is in essence nothing but the metabolism of the living matter, or of the plasm. Recent physiologists, especially Max Verworn and Max Kassowitz, have pointed out, in opposition to modern vitalism, that "life consists in a continuous alternation between the up-build and the decay of the highly-complicated chemical unities of the protoplasm. And if this conception is admitted, we may rightly say that we know what we mean by death. If death is the cessation of life, we must mean by that the cessation of the alternation between the up-build and the dissolution of the molecules of protoplasm; and as each of the molecules of protoplasm must break up again shortly after its formation, we have in death to deal only with the definite cessation of reconstruction in the destroyed plasma-molecules. Hence a living thing is not finally dead—that is to say, absolutely incompetent to discharge any further vital function—until the whole of its plasma-molecules are destroyed." In the exhaustive justification with which Kassowitz follows up this definition in the fifteenth chapter of his *General Biology*, the natural causes of physiological death are fully described.

Among the numerous and contradictory views of recent biologists on the nature of death we find many errors and misunderstandings, due to a lack of clear distinction between the duration of the living matter in general and that of the individual life-form. This is particularly noticeable in the contradictory views which

have been elicited by August Weismann's theory (1882) of the immortality of the unicellulars. I have shown in the eleventh chapter of the *Riddle* that it is untenable. But as the distinguished zoologist has again taken up his theory with energy in his instructive *Lectures on the Theory of the Descent* (1902), and has added to it erroneous observations on the nature of death, I am obliged to return to the point. Precisely because this interesting work gives most valuable support to the theory of evolution, and maintains Darwin's theory of selection and its consequences with great effect, I feel it is necessary to point out considerable weaknesses and dangerous errors in it. The chief of these is the important theory of the germ-plasm and the consequent opposition to the inheritance of acquired characteristics. Weismann deduces from this a radical distinction between the unicellular and the multicellular organisms. The latter alone are mortal, the former immortal; "between the unicellular and the multicellular lies the introduction of physiological—that is to say, normal—death." We must say, in opposition to this, that the physiological individuals *(bionta)* among the protista are just as limited in their duration as among the histona. But if the chief stress in the question is laid, not on the individuality of the living matter, but on the continuity of the metabolic life-movement through a series of generations, it is just as correct to affirm a partial immortality of the plasm for the multicellulars as for the unicellulars.

The immortality of the unicellulars, on which Weismann has laid so much stress, can only be sustained for a small part of the protists even in his own sense—namely, for those which simply propagate by cleavage, the chromacea and bacteria among the monera (chap.

ix.), the diatomes and paulotomes among the protophyta, and a part of the infusoria and rhizopods among the protozoa. Strictly speaking, the individual life is destroyed when a cell splits into two daughter-cells. One might reply with Weismann that in this case the dividing unicellular organism lives on as a whole in its offspring, and that we have no corpse, no dead remains of the living matter, left behind. But that is not true of the majority of the protozoa. In the highly developed ciliata the chief nucleus is lost, and there must be from time to time a conjugation of two cells and a mutual fertilisation of their secondary nuclei, before there can be any further multiplication by simple cleavage. However, in most of the sporozoa and rhizopoda, which generally propagate by spore formation, only one portion of the unicellular organism is used for this; the other portion dies, and forms a "corpse." In the large rhizopods (thalamophora and radiolaria) the spore-forming inner part, which lives on in the offspring, is smaller than the decaying outer portion, which becomes the corpse.

Weismann's view of the secondary "introduction of physiological death in the multicellulars" is just as untenable as his theory of the immortality of the unicellulars. According to this opinion, the death of the histona—both the metaphyta and metazoa—is a purposive outcome of adaptation, only introduced by selection when the multicellular organism has reached a certain stage of complexity of structure, which is incompatible with its original immortality. Natural selection would thus kill the immortal and preserve only the mortal; it would interfere with the multiplication of the immortals in the bloom of their years, and only use the mortal for rearing posterity. The curious conclusions

which Weismann reached in developing this theory of death, and the striking contradictions to his own theory of the germ-plasm which he fell into, have been pointed out by Kassowitz in the 49th chapter of his *General Biology*. In my opinion, this paradoxical theory of death has no more basis than the germ-plasm theory he has ingeniously connected with it. We may admire the subtlety and depth of the speculations with which Weismann has worked out his elaborate molecular theory. But the nearer we get to its foundations the less solid we find them. Moreover, not one of the many supporters of the theory of germ-plasm has been able to make profitable use of it in the twenty years since it was first published. On the other hand, it has had an evil influence in so far as it denied the inheriting of acquired characters, which I hold, with Lamarck and Darwin, to be one of the soundest and most indispensable supports of the theory of descent.

In discussing the question of the real causes of death, we confine our attention to normal or physiological death, without considering the innumerable causes of accidental or pathological death, by illness, parasites, mishaps, etc. Normal death takes place in all organisms when the limit of the hereditary term of life is reached. This limit varies enormously in different classes of organisms. Many of the unicellular protophyta and protozoa live only a few hours, others several months or years; many one-year plants and lower animals live only a summer in our temperate climate, and only a few weeks or months in the arctic circle or on the snow-covered Alps. On the other hand, the larger vertebrates are not uncommonly a hundred years old, and many trees live for a thousand years. The normal span of life has been determined in all species in the course of their evolution by adaptation to special conditions, and has then been transmitted to

offspring by heredity. In the latter, however, it is often subject to considerable modifications.

The organism has been compared, on the modern "machine theory" of life, to an artificially constructed mechanism, or an apparatus in which the human intelligence has put together various parts for the attainment of a certain end. This comparison is inapplicable to the lowest organisms, the monera, which are devoid of such a mechanical structure. In these primitive "organisms without organs" (chromacea and bacteria) the sole cause of life is the invisible chemical structure of the plasm and the metabolism effected by this. As soon as this ceases death takes place (*cf.* chap. ix.). In the case of all other organisms the comparison is useful in so far as the orderly co-operation of the various organs or parts accomplishes a certain task by the conversion of virtual into active force. But the great difference between the two is that in the case of the machine the regularity is due to the purposive and consciously acting will of man, whereas in the case of the organism it is produced by unconscious natural selection without any design. On the other hand, the two have another important feature in common in the limited span of life which is involved in their being used up. A locomotive, ship, telegraph, or piano, will last only a certain number of years. All their parts are worn out by long use, and, in spite of all repairing, become at last useless. So in the case of all organisms, the various parts are sooner or later worn out and rendered useless; this is equally true of the organella of the protist and the organs of the histon. It is true that the parts may be repaired or regenerated; but sooner or later they cease to be of service, and become the cause of death.

When we take the idea of regeneration, or the

recuperation of parts that have been rendered useless, in the widest sense, we find it to be a universal vital function of the greatest importance. The whole metabolism of the living organism consists in the assimilation of plasm, or the replacing of the plasma-particles which are constantly used up by dissimilation (*cf.* chap x.). Verworn has given the name of *biogens* to the hypothetical molecules of living matter—which I regard with Hering as endowed with memory, and (1875) have called plastidules. He says: "The biogens are the real vehicles of life. In their constant decay and reconstruction consists the process of life, which expresses itself in the great variety of vital phenomena." The relation of assimilation (the building-up of the biogens) to dissimilation (the decay of the biogens) may be expressed by a fraction to which the name *biotonus* is given A/D. It is of radical importance in the various phenomena of life. The variations in the size of this fraction are the cause of all change in the life-expression of every organism. When the biotone increases, and the metabolism quotient becomes more than one, we have growth; when, on the other hand, it falls below one, and the biotone decreases, we have atrophy, and finally death. New biogens are constructed in *regeneration*. In *generation* or reproduction groups of biogens (as germplasm) are released from the parent in consequence of redundant growth, and form the foundation of new individuals.

The phenomena of regeneration are extremely varied, and have of late years been made the subject of a good deal of comprehensive experiment, especially on the side of what is called "mechanical embryology." Many of these experimental embryologists have drawn far-reaching conclusions from their somewhat narrow experiments,

and have partly urged them as objections to Darwinism. They imagine that they have disproved the theory of selection. Most of these efforts betray a notable lack of general physiological and morphological knowledge. As they also generally ignore the biogenetic law, and take no account of the fundamental correlation of embryology and stem history, we can hardly wonder that they reach the most absurd and contradictory conclusions. Many examples of this will be found in the *Archiv für Entwickelungsmechanik*. When, however, we make a comprehensive survey of the interesting field of regeneration processes, we discover a continuous series of development from the simplest repair of plasm in the unicellular protists to the sexual generation of the higher histona. The sperm-cells and ova of the latter are redundant growth-products, which have the power of regenerating the whole multicellular organism. But many of the higher histona have also the capacity to produce new individuals by regeneration from detached pieces of tissue, or even single cells. In the peculiar mode of metabolism and growth which accompanies these processes of regeneration, the memory of the plastidule, or the unconscious retentive power of the biogens, plays the chief part (cf. my *Perigenesis of the Plastidule*, 1875). In the most primitive kinds of the unicellular protists we find the phenomena of death and regeneration in the simplest form. When an unnucleated moneron (a chromaceum or bacterium) divides into two equal halves, the existence of the dividing individual comes to an end. Each half regenerates itself in the simplest conceivable way by assimilation and growth, until it, in turn, reaches the size of the parent organism. In the nucleated cells of most of the protophyta and protozoa it is more complicated, as the

nucleus becomes active as the central organ and regulator of the metabolism. If an infusorium is cut into two pieces, only one of which contains the nucleus, this one alone grows into a complete nucleated cell; the unnucleated portion dies, being unable to regenerate itself.

In the multicellular body of the tissue-forming organisms we must distinguish between the partial death of the various cells and the total death of the whole organism, or cell-state, which they make up. In many of the lower tissue-plants and tissue-animals the communal link is very loose and the centralisation slight. Odd cells or groups of cells may be set loose, without any danger to the life of the whole histon, and grow into new individuals. In many of the algæ and liverworts (even in the *bryophyllum*, closely related to the stone-crop, or *sedum*)—as well as in the common fresh-water polyp, hydra, and other polyps—every bit that is cut off is capable of growing into a complete individual. But the higher the organisation is developed and the closer the correlation of the parts and their co-operation in the life of the centralised stock or person, the slighter we find the regenerative faculty of the several organs. Even then, however, many used-up cells may be removed and replaced by regenerated new cells. In our own human organism, as in that of the higher animals, thousands of cells die every day, and are replaced by new cells of the same kind, as, for instance, epidermic cells at the surface of the skin, the cells of the salivary glands or the mucous lining of the stomach, the blood-cells, and so on. On the other hand, there are tissues that have little or nothing of this repairing power, such as many of the nerve-cells, sense-cells, muscle-cells, etc. In these cases a number of constant cell-individuals remain with their nucleus

throughout life, although a used-up portion of their cell-body may be replaced by regeneration from the cytoplasm. Thus our human body, like that of all the higher animals and plants, is a "cell-state" in another sense. Every day, nay, every hour, thousands of its citizens, the tissue-cells, pass away, and are replaced by others that have arisen by cleavage of similar cells. Nevertheless, this uninterrupted change of our personality is never complete or general. There is always a solid ground-work of conservative cells, the descendants of which secure the further regeneration.

Most organisms meet their death through external or accidental causes—lack of sufficient food, isolation from their necessary environment, parasites and other enemies, accidents and disease. The few individuals who escape these accidental causes of death find the end of life in old age or senility, by the gradual decay of the organs and dwindling of their functions. The cause of this senility and the ensuing natural death is determined for each species of organisms by the specific nature of their plasm. As Kassowitz has lately pointed out, the senility of individuals consists in the inevitable increase in the decay of protoplasm and the metaplastic parts of the body which this produces. Each metaplasm in the body favours the inactive break-up of protoplasm, and so also the formation of new metaplasms. The death of the cells follows, because the chemical energy of the plasm gradually falls off from a certain height, the acme, of life. The plasm loses more and more the power to replace by regeneration the losses it sustains by the vital functions. As, in the mental life, the receptivity of the brain and the acuteness of the senses gradually decay, so the muscles lose their energy, the bones become fragile, the skin dry and withered, the elasticity

and endurance of the movements decrease. All these normal processes of senile decay are caused by chemical changes in the plasm, in which dissimilation gains constantly on assimilation. In the end they inevitably lead to normal death.

While the gradual decay of the bodily forces and the senile degeneration of the organs must necessarily cause the death of the soundest organism in the end, the great majority of men pass away through illness long before this normal term of life is reached. The external causes of this are the attacks of enemies and parasites, accidents, and unfavourable conditions of life. These cause changes in the tissues and their component cells, which first occasion the partial death of particular sections, and then the total death of the whole individual. The modifications of the living matter which produce disease and premature death are called *necrobioses*. They consist partly of *histolyses*—that is to say, degeneration of the cells by atrophy, dissolution, withering (mortification), or colliquation ; and partly of *metaplasmosisms*, or metamorphoses of the plasm—fatty, mucous, chalky, or amyloid metamorphoses of the cells. It was the great merit of Rudolph Virchow that he proved, in his epoch-making *Cellular Pathology* (1858), that all diseases in man and other organisms may be reduced to such modifications of the cells which make up the tissues. Hence disease, with its pain, is a physiological process, a life under injurious and dangerous conditions. As in all normal vital phenomena, so in abnormal or pathological, the ultimate ground must be sought in the physical and chemical processes in the plasm. Pathology is a part of physiology. This discovery has cut the ground from under the older notion of disease as a special entity, a devil, or a divine punishment.

The natural physical explanation of death, which has been made possible by modern physiology and pathology, has shattered, not only all the old superstitious ideas about disease and death, but also a number of important metaphysical dogmas which built upon them. Such was, for instance, the naïve belief in a conscious Providence, controlling the fate of individuals and determining their death. I do not fail to appreciate the great subjective value which such a trust in a protecting Providence has for men amid their countless dangers. We may envy the childish temper for the confidence and hope which it derives from this belief. But as we do not seek to have our emotions gratified by poetic fictions, we are bound to point out that reason cannot detect the shadow of a proof of the existence and action of this conscious Providence, or "loving Father in heaven." We read daily in our journals of accidents and crimes of all kinds that cause the unexpected death of happy human beings. Every year we read with horror the statistics of the thousands of deaths from shipwreck and railway accidents, earthquakes and landslips, wars and epidemics. And then we are asked to believe in a loving Providence that has decreed the death of each of these poor mortals! We are asked to console ourselves in face of the tragedy with the hollow phrases: "God's will be done," or "God's ways are wonderful." Simple children and dull believers may soothe themselves with such phrases. They no longer impose on educated people in the twentieth century, who prefer a full and fearless knowledge of the truth.

When our monistic and rational conception of death is described as dreary and hopeless, we may answer that the prevalent dualistic view is merely an outcome of hereditary habits of thought and mystic training in early

youth. When these are displaced by progressive culture and science, it will be clear that man has lost nothing, but gained much, as regards his life on earth. Convinced that there is no eternal life awaiting him, he will strive all the more to brighten his life on earth and rationally improve his condition in harmony with that of his fellows. If it is objected that then everything will depend on mere "chance," instead of being controlled by a conscious Providence or a moral order of the world, I must refer the reader for my reply to the close of the fourteenth chapter of the *Riddle*, where I have dealt with fate, providence, end, aim, and chance. And if it is further claimed that our realistic view of life leads to pessimism, there is no better ground for such an accusation.

I have given, in the eleventh chapter of the *Riddle*, the scientific reasons which forbid us to accept the personal immortality of the soul. But as the most vehement attacks have been made on this chapter by metaphysicians of the prevailing school and by Christian theologians, I must return to the question here. I am convinced, from numbers of letters I have received and conversation with educated people of all classes, that no other dogma is so firmly established and highly valued as athanatism, or the belief in personal immortality. Most men will not give up at any price the hope that a better life awaits them beyond the grave, which will compensate them for all the pain and suffering they endure here. In the picturing of this future life the medieval geocentric idea still forms the chief feature. Troels-Lund has shown, in his *Idea of Heaven and of the World*, how this theory still dominates the metaphysics of the majority of men; in spite of Copernicus and Laplace, heaven is still for most people

the semi-circular blue glass-bell that over-arches the earth. We still hear the praises of our life in this heaven sung daily in sermons and speeches and festive orations. The orator extends his right hand "upwards" to the infinite starry space of heaven, forgetting that the radius of the direction he is pointing towards changes every second, and in twelve hours reaches the precisely opposite direction, and becomes "downwards." Other believers endeavour to be still more concrete, and point out definite celestial bodies as the homes of immortal souls. Modern cosmology, astronomy, and geology entirely exclude these pretty fictions from science; and modern psychology, physiology, ontogeny, and phylogeny rigorously refuse an inch of ground for athanatism.

Optimism regards the world on its good and bright and admirable side: pessimism looks to the shades and tragedies of life. In some philosophic and religious systems one or other of these tendencies is consistently and exclusively worked out; but in most systems the two are mingled. Pure and consistent realism is generally neither optimistic nor pessimistic. It takes the world as it is, a unified whole, the nature of which is neither good nor bad. Dualistic idealism, however, generally combines the two, and distributes them between its two worlds; it describes this world as a "vale of tears," and the next as a glorious city of joy and happiness. This view is a conspicuous feature in most of the dualistic religions, and has still a considerable influence, both practically and theoretically, on the minds of educated people.

The founder of systematic optimism was Gottfried Leibnitz, whose philosophy sought to achieve an ingenious harmony between divergent systems, but is really a form of dynamism, or a monism somewhat akin to the energism

of Ostwald. Leibnitz gave a compendious statement of his system in his *Monadology* (1714). He taught that the world consists of an infinite number of monads (which almost correspond to our psychic atoms), but this pluralism was converted into a monism by making God, as the central monad, bind all together in a substantial unity. In his *Theodicy* (1710) he taught that God (the "all-wise, all-good, and almighty creator of the world") had with perfect consciousness created "the best of all possible worlds"; that his infinite goodness, wisdom, and power are seen everywhere in the pre-established harmony of things; but that the individual human being, and humanity taken as a whole, have only a limited capacity for development. The man who knows the real features of the world, who has honestly confronted the tragic struggle for life that rules throughout living nature, who has sympathy for the infinite sum of misery and want of every kind in the life of men, can scarcely understand how an acute and informed thinker like Leibnitz could entertain such optimism as this. It would be more intelligible in the case of a one-sided and nebulous metaphysician like Hegel, who held that "all that is real is rational and all that is rational is real."

Pessimism is the direct opposite of systematic optimism. While the one holds the universe to be the best, the other regards it as the worst, of all possible worlds. This pessimistic conception has found expression in the oldest and most popular religions of Asia, Brahmanism and Buddhism. Both these Hindoo religions were orginally pessimistic, and at the same time atheistic and idealistic. Schopenhauer especially pointed out this, declaring that they were the most perfect of all religions, and importing their leading ideas into his own system. He considers it "a glaring absurdity to attempt

to prove this miserable world the best of all possible ones—this cock-pit of tortured and suffering beings, who can only survive by destroying each other, in which the capacity for pain grows with knowledge, and so reaches its height in man. Truly optimism cuts so sorry a figure in this theatre of sin, suffering, and death that we should have to regard it as a piece of sarcasm if Hume had not given us an explanation of its origin (the wish to flatter God and hope for some result from it). To the palpable sophistry of Leibnitz, who would prove this world the best of all possible, we can oppose a strict and honest proof that it is the worst of all possible." However, neither Schopenhauer nor the most important of modern pessimists, Edward Hartmann, has drawn the strict practical conclusion from pessimism. That would be to deny the will to live, and put an end to suffering by suicide.

The mention of suicide as the logical consequence of pessimism may serve as an occasion to glance at the curious and contradictory views that are expressed about it. There are few problems of life (apart from immortality and the freedom of the will) on which such absurd and contradictory things have been said even down to our own time. The theist who regards life as a gift of God may hesitate to reject or return it—although the offering of oneself as a victim for other men is considered a high virtue. Most educated people still look upon suicide as a great sin, and in some countries (such as England) the attempt is punished by law. In the Middle Ages, when a hundred thousand men were burned alive for heresy or witchcraft, suicides were punished by a disgraceful burial. As Schopenhauer says: "Clearly there is nothing in the world to which a man has a plainer right than his own life and person. It is simply

ridiculous for criminal justice to deal with suicide." The advance of embryology in the last thirty years has made it clear that the individual life of a man (and all other vertebrates) begins at the moment when the male sperm-cell and the maternal ovum coalesce. In this blind chance plays an important part, as in so many other important aspects of life—taking "chance" in the scientific sense, which I have explained in chap. xiv. of the *Riddle*. Hence, the real cause of personal existence is not the favour of the Almighty, but the sexual love of one's earthly parents; very often this consequence of the act of love has been anything but desired. If then the circumstances of life come to press too hard on the poor being who has thus developed, without any fault of his, from the fertilised ovum—if, instead of the hoped-for good, there come only care and need, sickness and misery of every kind—he has the unquestionable right to put an end to his sufferings by death. Every religion assents to this under certain conditions, even Christianity when it says: "If thine eye scandalise thee, cast it from thee." It is true that the conventional morality condemns suicide under any circumstances; but the reasons it alleges are ridiculously slight, and are not improved by having the mantle of religion wrapped about them.

The voluntary death by which a man puts an end to intolerable suffering is really an act of redemption. We should, therefore, describe it as self-redemption, and look on it with Christian sympathy, not brand it pharisaically as "self-murder." As a fact, this contemptuous phrase has no meaning, since murder is the taking away of a man's life against his will, while the suicide dies voluntarily. Hence, he usually deserves our sympathy, not contempt, and certainly not punishment. Our conventional morality is, as so often happens, full of senseless

contradictions. Modern States have introduced conscription; they demand that every citizen shall give up his life for his country on command, and kill as many other men as he can (an admirable commentary on the Scriptural "Love your enemies") for some political reason or other. But they never secure to each citizen the means of honourable existence and free development of his personality—not even the right to work by which he may maintain himself and his family.

I fully recognise the advance that social politics has made in improving the conditions of the poorer classes, the promotion of hygiene and education and the bodily and mental welfare of citizens; but we are still very far from the attainable ideal of general prosperity and happiness which reason dictates to every civilised nation. Misery and want are increasing among the poor, as the division of labour and over-population increase. Thousands of strong and active men come to grief every year without any fault of theirs, often precisely because they were quiet and honest; thousands are hungry because, with the best will in the world, they cannot find work; thousands are sacrificed to the heartless demands of our iron age of machinery with its exacting technical and industrial requirements. On the other hand, we see thousands of contemptible characters prospering because they have been able to deceive their fellows by unscrupulous speculations, or because they have flattered and served the higher authorities. It is no wonder that the statistics of suicide increase so much in the more civilised communities. No feeling man who has any real "Christian love of his neighbour" will grudge his suffering brother the eternal rest and the freedom from pain which he has obtained by his self-redemption.

The seventh petition of the Lord's Prayer, which is repeated daily by millions of Christians, is: "Deliver us from evil." Luther explains this as a prayer to be saved "from all evil of body and soul" in this life and the next. When we consider this in the light of our monistic principles, we have naturally to set aside the superstitious ideas of the Middle Ages regarding the future life, and deal only with the petition as regards this life. The number and variety and gravity of these evils have grown in civilised communities in the nineteenth century, notwithstanding all the progress we have made in art and science and the rational reform of our personal and social life. Civilisation has gained infinitely in value by the change we have made in our conceptions of time and space in this age of steam and electricity. We can make our domestic and public life much pleasanter, and avail ourselves of a far greater number of luxuries, than was possible to our grandfathers a hundred years ago. But all this has caused a much greater expenditure of nerve-energy. The brain has to bear a much greater strain, and is worn out earlier, the body is more stimulated and over-worked than it was a hundred years ago. Many diseases of modern civilisation are making appalling progress; neurasthenia, especially, and other diseases of the nerves, carry off more victims every year. Our asylums grow bigger and more numerous every year, and we have sanatoria on every side in which the baited victim of modern civilisation seeks refuge from his evils. Some of these evils are quite incurable, and the sufferers have to meet a certain death in terrible pain. Many of these poor creatures look forward to their redemption from evil and the end of their miserable lives. The important question arises whether, as compassionate men, we should be justified

in carrying out their wish and ending their sufferings by a painless death.

This question is of great importance, both in practical philosophy and in juridical and medical practice, and, as opinions differ very much on the subject, it seems advisable to deal with it here. I start from my own personal opinion, that sympathy is not only one of the noblest and finest functions of the human brain, but also one of the first conditions of the social life of the higher animals. The precepts of Christian charity, which the Gospels rightly place in the very foreground of morality, were not first discovered by Christ, but they were successfully urged by him and his followers at a time when refined selfishness threatened the Roman civilisation with decay. These natural principles of sympathy and altruism had arisen thousands of years before in human society, and are even found among all the higher animals that live a social life. They have their first roots in the sexual reproduction of the lower animals, the sexual love and the care of the young on which the maintenance of the species depends. Hence the modern prophets of pure egoism, Friedrich Nietzsche, Max Stirner, etc., commit a biological error when they would substitute their morality of the strong for universal charity, and when they ridicule sympathy as a weakness of character or an ethical blunder of Christianity. It is just in its insistence on sympathy that the Christian teaching is most valuable, and this part of its system will survive long after its dogmas have sunk into oblivion. However, this lofty duty must not be confined to men, but extended to "our relations," the higher vertebrates, and, in fact, to all animals whose brain-organisation seems to point to the possession of sensation and a consciousness of pleasure and pain. Thus, for instance, in

the case of the domestic animals which we use daily in our service, and which have an undoubted psychic affinity to ourselves, we must take care to increase their pleasures and mitigate their sufferings. Faithful dogs and noble horses, with which we have lived for years and which we love, are rightly put to death and relieved from pain when they fall hopelessly ill in old age. In the same way we have the right, if not the duty, to put an end to the sufferings of our fellow-men. Some severe and incurable disease makes life unbearable for them, and they ask for redemption from evil. However, medical men hold very different opinions on the matter, as I have found in conversation with them. Many experienced physicians, who practise their profession in a spirit of sympathy and without dogmatic prejudice, have no scruple about cutting short the sufferings of the incurable by a dose of morphia or cyanide of potassium when they desire it; very often this painless end is a blessing both to the invalids and their families. However, other physicians and most jurists are of opinion that this act of sympathy is not right, or is even a crime; that it is the duty of the physician to maintain the life of his patients as long as he can in all circumstances. I should like to know why.

While I am dealing with this important and—for the medical conscience—difficult question of social ethics, I may take the opportunity to consider the general attitude of physicians to the monistic philosophy. It is now half a century since I visited the wards in the Julius hospital at Würtzburg as a medical student. It is true that—happily for me and my patients!—I practised the profession only for a short time after I had passed my examinations in 1857; but the thorough acquaintance with the human organism, its anatomic structure and physiological

functions, which I then obtained, has been of incalculable service to me. I owe to it not only the solid empirical foundation of the special study of my life, zoology, but also the monistic tendency of my whole system. As the medical training in its widest sense includes anthropology—and so should include psychology also—its value for speculative philosophy cannot be exaggerated. The scholastic metaphysicians who still regard the chairs of philosophy at our universities as their monopoly would have avoided most of their dualistic errors if they had had a thorough training in human anatomy, physiology, ontogeny, and phylogeny. Even pathology, the science of the diseased organism, is very instructive for the philosopher. The psychologist especially acquires, by the study of mental disease and the visiting of the asylum wards, a profound insight into the mental life which no speculative philosophy could give him. There are few experienced and thoughtful physicians who retain the conventional belief in the immortality of the soul and God. What would the immortal soul do on the other side of eternity when it is already utterly ruined in this life, or was even born as an idiot? How can a just God condemn the criminal to the fires of hell when he himself has tainted the man with an hereditary bias, or has placed him in an environment in which, seeing the absence of free-will, crime was a necessity for him? And how can this all-loving God answer for the immeasurable sum of want and misery, and pain and unhappiness, which he sees accumulated before him every year in the lives of families and States, cities and hospitals? It is no wonder that the old saying ran: *Ubi tres medici, duo sunt athei* (Of three doctors two are sure to be atheists). One of my medical colleagues was an old, experienced, and sympathetic physician who had travelled all over the

world, and had then, as director of a large hospital, been a close witness of the sufferings of humanity. Religiously educated by pious parents, and endowed with keen sensitiveness, he was, after long struggles, forced by his medical studies to part with the faith of his boyhood—like myself, in his twenty-first year. We were talking about the great mysteries of life shortly before his death, and he said to me: "I have been unable to reconcile belief in the immortality of the soul and the freedom of the will with my psychological experiences, and I have been just as unable to discover throughout the whole world a single trace of a moral order or a beneficent providence. If it is true that an intelligent Deity rules the world, he cannot be a God of love, but an all-powerful demon, whose constant entertainment is an eternal and merciless play of being and becoming, building up and destroying." However, we do still find here and there informed and intelligent physicians who adhere to the three central dogmas of metaphysics—a proof of the immense power of dogmatic tradition and religious prejudice.

We must class as a traditional dogma the widespread belief that man is bound under all circumstances to maintain and prolong life, even when it has become utterly useless—a source of pain to the incurable and of endless trouble to his friends. Hundreds of thousands of incurables—lunatics, lepers, people with cancer, etc. —are artificially kept alive in our modern communities, and their sufferings are carefully prolonged, without the slightest profit to themselves or the general body. We have a strong proof of this in the statistics of lunacy and the growth of asylums and nerve-sanatoria. In Prussia alone there were 51,048 lunatics cared for in the asylums (6,000 in Berlin) in 1890; more than one-tenth

of them were quite incurable (4,000 of them suffering from paralysis). In France, in 1871, there were 49,589 in the asylums (or 13.8 per thousand of the population), and in 1888 there were 70,443 (or 18.2 per thousand); thus, in the course of seventeen years, the absolute number of the unsound rose nearly 30 per cent. (29.6), while the total population only increased 5.6 per cent. In our day the number of lunatics in civilised countries is, on the average, 5–6 per thousand. If the total population of Europe is put at 390–400 millions, we have at least two million lunatics among them, and of these more than 200,000 are incurable. What an enormous mass of suffering these figures indicate for the invalids themselves, and what a vast amount of trouble and sorrow for their families, what a huge private and public expenditure! How much of this pain and expense could be spared, if people could make up their minds to free the incurable from their indescribable torments by a dose of morphia! Naturally this act of kindness should not be left to the discretion of an individual physician, but be determined by a commission of competent and conscientious medical men. So, in the case of other incurables and great sufferers (from cancer, for instance), the "redemption from evil" should only be accomplished by a dose of some painless and rapid poison when they have expressed a deliberate wish (to be afterwards juridically proved) for this, and under the control of an authoritative commission.

The ancient Spartans owed a good deal of their famous bravery, their bodily strength and beauty, as well as their mental energy and capacity, to the old custom of doing away with new-born children who were born weakly or crippled. We find the same custom to-day among many savage races. When I pointed out the

advantages of this Spartan selection for the improvement of the race in 1868 (chap. vii. of the *History of Creation*) there was a storm of pious indignation in the religious journals, as always happens when pure reason ventures to oppose the current prejudices and traditional beliefs. But I ask: What good does it do to humanity to maintain artificially and rear the thousands of cripples, deaf-mutes, idiots, etc., who are born every year with an hereditary burden of incurable disease? Is it not better and more rational to cut off from the first this unavoidable misery which their poor lives will bring to themselves and their families? It is no use to reply that religion forbids it. Christianity also bids us give up our life for our brethren, and to cast it from us when it hurts us —that is to say, when it only causes useless pain to us and our friends. The truth is, the opposition is only due to sentiment and the power of conventional morality —that is to say, to the hereditary bias which is clothed in early youth with the mantle of religion, however irrational and superstitious be its foundation. Pious morality of this sort is often really the deepest immorality. "Laws and rights creep on like an eternal sickness"; this is equally true of the social customs and morals on which laws and rights are founded. Sentiment should never be allowed to usurp the place of reason in these weighty ethical questions. As I pointed out in the first chapter of the *Riddle*, sentiment is a very amiable, but a very dangerous, function of the brain. It has no more to do with the attainment of the truth than what is called revelation. That is well seen in Kant's dualism, for his *mundus intelligibilis* is essentially an outcome of his religious sentimentality.

## Chapter VI.

# PLASM

Plasm is the universal living substance. Definition of protoplasm, chemically and morphologically. Physical character. Viscous condition. Chemical analysis. Colloid character of albumin. Albuminoid molecules. Elementary structure of plasm. Work of plasm. Protoplasm and metaplasm. Structures of metaplasm. Frothy structure. Skeletal structure. Fibrous structure. Granular structure. Molecular structure. Plasma molecules. Plastidules and biogens. Micella and biophora. Caryoplasm and cytoplasm. Nuclear matter. Chromatin and achromin. Nucleolus and centrosoma. Caryotheka and caryolymph. Cellular matter. Plasma products. Internal plasma products. External plasma products. Cell membranes. Intercellular matter. Cuticular matter.

By plasm, in the widest sense of the word, we mean the living matter, or all bodies that are found to constitute the material foundations of the phenomena of life. It is usual to give this matter the name of protoplasm; but this older and historically important designation has suffered so many changes of meaning through the variety of its applications that it is better now to use it only in the narrower sense. Moreover, recent research on protoplasm has been greatly developed, and several new names have been invented, which are formed from the word "plasm" with a qualifying prefix. These are special varieties of the general idea of plasm, or special modifications of the general matter, such as metaplasm, archiplasm, and so on.

The botanist, Hugo Mohl, who first introduced the name "protoplasm" in 1846, used it to designate a part of

the contents of the ordinary plant-cell—namely, the viscous matter that Schleiden called "cell-mucus," which is found on the inner surface of the cell-wall, and often forms a varying net-work or skeleton in the watery fluid in the cell, and exhibits characteristic movements. Mohl gave the name of "primordial skin" to this important wall-layer (the chief element of the plant-cell), and called the material of it, as being chemically different from the other parts of the cell, *protoplasm*—that is to say, the first (*proton*) or earliest formation of the organism. It is important to notice that Mohl, the author of the name, conceived it in a purely chemical, not a morphological, sense, like Oscar Hertwig and other recent cytologists. I intend to retain this early chemical idea of protoplasm—or, briefly, plasm. It was also taken in this sense by Max Schultze, who pointed out (in 1860) its extreme significance and wide distribution in all living cells, and introduced an important reform of the cell-theory which we will see later.

The mixing of the chemical and the morphological ideas of protoplasm has been very mischievous in recent biology, and has led to great confusion. It generally comes from a failure to formulate clearly the difference between the two essential elements of the modern notion of the cell—the anatomic distinction between the nucleus and the body of the cell. The internal nucleus (or *caryon*) had the appearance of a solid, definite, morphologically distinct constituent of the cell ; the outer and softer mass which we now call the cell-body (*celleus* or *cytosoma*) seemed to be a formless and only chemically definable protoplasm. It was only discovered at a later date that the chemical composition of the nucleus is closely akin to that of the cell-body, and that we may properly associate the *caryoplasm* of the one with the

*cytoplasm* of the other under the general heading of *plasm*. All the other materials that we find in the living organism are products or derivatives of the active plasm.

In view of the extraordinary significance which we must assign to the plasm—as the universal vehicle of all the vital phenomena (or "the physical basis of life," as Huxley said)—it is very important to understand clearly all its properties, especially the chemical ones. This is rendered somewhat difficult from the circumstance that the plasm is, in most of the organic cells, closely bound up with other substances—the various plasma-products; it can rarely be isolated in its purity, and can never be had pure in any quantity. Hence we are for the most part dependent on the imperfect, and often ambiguous, results of microscopic and microchemical research.

In every case where we have with great difficulty succeeded in examining the plasm as far as possible and separating it from the plasma-products, it has the appearance of a colourless, viscous substance, the chief physical property of which is its peculiar thickness and consistency. The physicist distinguishes three conditions of inorganic matter—solid, fluid, and gaseous. Active living protoplasm cannot strictly be described as either fluid or solid in the physical sense. It presents an intermediate stage between the two which is best described as viscous; it is best compared to a cold jelly or solution of glue. Just as we find the latter substance in all stages between the solid and the fluid, so we find in the case of protoplasm. The cause of this softness is the quantity of water contained in the living matter, which generally amounts to a half of its volume and weight. The water is distributed between the plasma

molecules, or the ultimate particles of living matter, in much the same way as it is in the crystals of salts, but with the important difference that it is very variable in quantity in the plasm. On this depends the capacity for absorption or imbibition in the plasm, and the mobility of its molecules, which is very important for the performance of the vital actions. However, this capacity of absorption has definite limits in each variety of plasm; living plasm is not soluble in water, but absolutely resists the penetration of any water beyond this limit.

The chemistry of living matter is the most important and interesting, but at the same time the most difficult and obscure, part of the whole of biological chemistry. In spite of the innumerable and careful investigations which have been made of it by the ablest physiologists and chemists in the second half of the nineteenth century, we are still far from a satisfactory solution of this fundamental problem of biology. This is due partly to the extraordinary difficulty of isolating pure living plasm and subjecting it to chemical analysis, and partly to the many errors and misunderstandings that have arisen through one-sided treatment of the subject, and especially through confusion of the chemical and morphological features of plasm. We can thus understand the contradictory views that are still put forward by distinguished chemists and physiologists, zoologists and botanists. As I cannot deal here with the very extensive, elaborate, and contradictory literature of the subject, I must be content to give a brief summary of the conclusions I have reached by my reading and my own studies of plasm (begun in 1859).

To begin with, we must clearly understand that protoplasm—in the most general sense in which we here take

it—is a *chemical* substance, not a "mixture of different substances," or a "mixture of a small quantity of solid matter with a good deal of fluid." As Richard Neumeister very well observes: "We seek the nature of protoplasm in the peculiar processes which take place in its constituent matter. Protoplasm is for us a chemical matter, so pronounced, in fact, that the highest chemical actions that we know of are embodied in it." I must, from my point of view, entirely reject Oscar Hertwig's conception of living matter as a "mixture" of a number of chemical elements; because chemistry applies this phrase to various gases and powdery substances which are completely indifferent to each other—a property which we certainly do not find in the constituents of protoplasm. When we speak of the living matter or protoplasm, the general phrase does not imply that the substance may not have a distinctive composition in each particular case. And when we find many biologists still conceiving protoplasm as a mixture of various substances, the error is generally due to a confusion of the chemical idea with the morphological, and to a belief that certain structural features of the plasm are primary, whereas they are only secondary, products of the vital process itself in the cell-body.

The older biologists who first introduced the name protoplasm and studied it carefully recognised that this living matter belonged to the albuminous (or proteid) group. The many characteristics which distinguish these nitrogenous carbon-compounds from all other chemical compounds—their behaviour towards acids and bases, their peculiar colour-reaction towards certain salts, their decomposition-products, etc.—are found in all the plasma-substances, and in all the other albuminoids. This is quite in agreement with the results of quantitative

analysis. However differently the various plasma-substances behave in detail, they always exhibit the same general composition as the other albuminoids out of the five "organogenetic elements"—namely, in point of weight, 51–54% carbon, 21–23% oxygen, 15–17% nitrogen, 6–7% hydrogen, and 1–2% sulphur. However, there is a good deal of variety and complication in the way in which the atoms of these five elements are combined in albumin and their molecules are grouped. Hence the question of the chemical nature of the plasma-substances compels us now to look for a moment at the larger group of albuminoids to which they belong.

The carbon-compounds which we comprise under the chemical title of the albumins or proteids are the most remarkable, but also, unfortunately, the least known, of all bodies. The attempt to examine them closely encounters extraordinary difficulties, greater than in any other group of chemical compounds. Everybody is familiar with the appearance of ordinary albumin, from the transparent viscous albumin that surrounds the yelk in the hen's egg, and which becomes a white, opaque, and solid mass when it is cooked. However, this special form of albumin, which we can get so easily in any quantity from the eggs of birds and reptiles, is only one of the innumerable kinds of albumin, or species of protein, that are to be found in the bodies of the various animals and plants. Chemists have hitherto tried in vain to master the chemical structure of these obscure protein-compounds. They are only rarely to be found in chemically pure form as crystals. As a rule, they are in the colloid form, or uncrystallised jelly-like masses, which offer a much greater resistance than crystals to the passage through a porous medium by diosmosis (see p. 40). However, although we have not yet succeeded

in penetrating the molecular constitution of the albumins, the laborious research of chemists has yielded some general results, which are of great importance for our purpose. We have, in the first place, a general idea of their molecular constitution.

Molecules are the smallest homogeneous parts into which a body can be divided without altering its chemical character. Hence the molecules of every chemical compound are made up of two or more atoms of different kinds. The greater the number of atoms in each compound, the higher is its molecular weight. The space between the molecules and their component atoms is filled with imponderable and highly elastic ether. As even the largest molecules occupy only a very tiny space, and remain far below the range of the most powerful microscope, all our ideas of their composition depend on general physical theories and special chemical hypotheses. Nevertheless, stereochemistry, the modern science of the molecular structure of chemical compounds, is not only a perfectly legitimate section of natural philosophy, but it yields the most important conclusions as to the mutual attractions of the elements and the invisible movements of the atoms in combining. It further enables us to calculate approximately the relative size of the molecules and the number of atoms that are grouped together in them. However, the albuminoids present the greatest difficulty of all in this calculation, and their structural features are still very obscure. Nevertheless, science has reached certain general conclusions, which we may formulate in the following propositions:—

1. The molecule of albumin is unusually large, and therefore its molecular weight is very high (higher than in most or all other compounds).

2. The number of atoms composing it is very large (probably much more than a thousand).

3. The disposition of the atoms and groups of atoms in the albuminous molecule is very complicated, and at the same time very unstable—that is to say, very changeable and easily altered.

These characters, which are ascribed to all albuminous bodies by modern chemistry, hold good of all plasma-substances; and, in fact, are true in a higher degree of these, as the metabolism of the living matter causes a constant displacement of the atoms. This is caused, according to the view of Franz Hofmeister and others, by the formation of ferments or enzyma—in other words, by catalysators of a colloidal structure. Verworn has, on physiological grounds, given the name of biogens to these plasma-molecules.

The profound insight which comparative anatomy has given us into the significance and nature of organs, and comparative histology into those of the cells, has naturally excited a desire to penetrate in the same way the mystery of the elementary structure of the plasm, the chief active constituent of the cell. The improved methods of modern cytology, and the great progress which this science of the cell owes to the microtome and to micro-chemistry with its delicate colouring processes, etc., have prompted many observers of the last three decades to study the finest structural features of the elementary organism, and on this foundation build hypotheses as to the elementary structure of protoplasm. In my opinion, all these theoretical ideas, in so far as they would explain the finer structure of pure plasm, have a very serious defect; they relate to microscopic structures which do not belong to the plasm as such (as a chemical body), but to the cell-body (or cytosoma), the chief active

constituent of which is certainly the plasm. These microscopic structures are not the efficient causes of the life-process, but products of it. They are phylogenetic outcomes of the manifold differentiations which the originally homogeneous and structureless plasm has undergone in the course of many millions of years. Hence I regard all these "plasma-structures" (the comb, threads, granules, etc.), not as original and primary, but as acquired and secondary. In so far as these structures affect the plasm as such, it must take the name of metaplasm, or a differentiated plasm, modified by the life-process itself. The true protoplasm, or viscous and at first chemically homogeneous substance, cannot, in my opinion, have any anatomic structure. We shall see, when we come to consider the monera, that very simple specimens of such organisms without organs still actually exist.

By far the greater part of the plasm that comes under investigation as active living matter in organisms is metaplasm, or secondary plasm, the originally homogeneous substance of which has acquired definite structures by phyletic differentiations in the course of millions of years. To this modified plasm we must oppose the original simple primary plasm, from the modification of which it has arisen. The name "protoplasm," in the narrower sense, could very properly be retained for this originally homogeneous form of structureless plasm; but, as the term has now almost lost definite meaning and is used in many different senses, it is, perhaps, better to call this pure homogeneous primary plasm *archiplasm*. It is still found—firstly, in the body of many (but not all) of the monera, part of the chromacea and bacteria, and the protamœba and protogenes; and, secondly, in the body of many very

young protists and tissue-cells. In the latter case, however, there is already a chemical differentiation of the inner caryoplasm and outer cytoplasm. When we examine these young cells under a high power of the microscope, with the aid of the modern colouring methods, their protoplasm seems to be perfectly homogeneous and structureless, or, at the most, there are merely very fine granules regularly distributed in it which are believed to be products of metabolism. This is best seen in many of the rhizopods, especially the amœbæ, thalamophora, and mycetozoa. There are large amœbæ, which thrust out strongly mobile feet from their unicellular body, broad, flap-like processes of the naked cell body which constantly change their form, size, and place. If they are killed and examined with the aid of the best methods of colouring, it is quite impossible to detect any structure in them; and this is also true of the pseudopodia of the mycetozoa and many other rhizopods. Moreover, the slow flowing movement of the fluid protoplasm shows clearly that there cannot be any composition out of fine fixed elements in the body. This is particularly clear in those amœbæ and mycetozoa in which a hyaline, firm, and non-granulated skin-layer *(hyaloplasm)* is more or less separated from a dark, softer, and granulated marrow-layer (polioplasm); as both of them are viscous and pass into each other without sharp limits, there cannot be any constant and fixed structural features in them.

Organic life—in its lowest and simplest form—is nothing but a form of metabolism, and therefore a purely chemical process. The whole vital activity of the chromacea, the simplest and oldest organisms that we know, is confined to that process of metabolism which we call plasmodomism or carbon-assimilation. The

homogeneous and structureless globules of protoplasm, which represent the whole frame of these primitive protophyta (chroococcus, aphanocapsa, etc.) in the simplest conceivable way, expend their whole vital power in the process of self-maintenance. They maintain their individuality by a simple metabolism; they grow by the addition of fresh plasm obtained by it, and they split up into two equal globules of plasm when the growth passes a certain limit—reproduction by cleavage, maintenance of the species. Thus these chromacea have neither special organs, or organella, that we can distinguish in their simple plasma-bodies, nor different functions in their life-process; it is wholly taken up with the primitive work of their vegetal metabolism. We shall see later on that this is a purely chemical process, something like catalysis in inorganic combinations; and for this neither special organs nor fine elementary structures in the plasm are needed. The "end" of their existence, self-maintenance, is attained just as simply as in the catalysis of any inorganic compound, or the formation of a crystal in its mother-water.

If we compare this very rudimentary life-process of the monera with that of the highly-differentiated protists (diatomes, desmidiacea, radiolaria, and infusoria), the biological distance between them seems to be immense; and it is, naturally, far greater when we extend the comparison to the histona, the highly-organised metaphyta and metazoa, in the bodies of which millions of cells co-operate in the work of the various tissues and organs.

In the great majority of cells—either the autonomous cells of the protists or the tissue-cells of the histona—we can detect more or less definite and constant fine structures in the plasm. We must regard these always as phyletic, secondary products of the life-process, and

so call the differentiated plasm by the name of metaplasm. The very different interpretations of the microscopic pictures which this metaplasm affords have led to a good deal of controversy. In this the desire to discover in these secondary plasma-structures the first causes of vital action, or the real elementary organella of the cell, has played a great part. The most important of the theories that have been formulated are those of the frothy structure, the skeletal structure, the fibrous structure, and the granulated structure of the plasm. All these theories of structure apply to plasm in general, but particularly to its two chief forms, the caryoplasm of the nucleus and the cytoplasm of the cell-body.

Among the many different attempts to discover a definite structure in living matter, the theory of the frothy structure (also called the honeycomb structure) has lately found the most favour. Otto Bütschli, of Heidelberg, especially, has endeavoured, on the basis of many years of careful study and experiment, to make it the foundation of his view of the plasm. It is undeniable that the living matter of many cells shows a delicate structure which may best be compared with fine soap-suds; innumerable globules are crowded close together in a fluid, and flatten each other by their pressure into polyhedrical shapes. In 1892 Bütschli artificially produced fine oil-suds by beating up cane sugar or potash in olive oil, and then put a small drop of the stuff in a drop of water under the microscope. The small particles of sugar then exercised an attractive action by diffusion on the particles of water; the latter penetrated into the oily matter, released the sugar, and formed tiny vesicles with it. As the vesicles of sugar do not mix with oil, they look like cavities isolated on all sides, and polyhedrically flattened by mutual pressure. The striking

resemblance of this artificially produced "oil soap-suds" to the natural and microscopically visible structures of many kinds of plasm is strengthened from the fact that Bütschli, Georg Quincke, and others, have also observed similar flowing movements in both; and as these apparently spontaneous movements can be explained physically and reduced to adhesion, imbibition, and other mechanical causes, there seemed a prospect of reducing the "vital" movements of the living and flowing plasm to purely physical forces. Quite recently Ludwig Rhumbler, of Göttingen, an authority on the rhizopods, has endeavoured to give in this sense a *Physical analysis of the vital phenomena in the cell.* To-day the froth theory is much the most popular of the many attempts to detect a fine plasm-structure as the essential anatomic foundation of an explanation of the physiological functions. It must be noted, however, that frequently very different phenomena are confused under this name, especially the coarser froth-formation by taking up water in the living matter and the invisible hypothetical molecular structure. Both these must be distinguished from the finer plasma-structure which is visible under a powerful microscope; but the limit between them is difficult to determine.

A second view of the finer structure of the plasm, which had been greatly esteemed before the acceptance of the froth theory, was formulated in 1875 by Carl Frommann and Carl Heitzmann, and supported by Leydig, Schwitz, and others. It puts another interpretation on the net-like appearance of the microscopic plasma-structure. It assumes that the plasma consists of a skeleton of fine threads or fibrils combined in the form of a net, and that these spread and cross in the body of the cell which is filled with fluid. It is also

compared to a sponge, and is said to have a spongy structure. We can artificially produce such a skeletal structure by, for instance, causing cogulation in a thick solution of glue or albumin by adding alcohol or chromic acid. It is unquestionable that there are these "plasma-skeletons" both in the nucleus and the body of the cell; but they are generally (if not always) secondary products of organisation in the elementary organism (or cell-organs), not primitive structures of its plasm. Moreover, an optical transverse action of a froth-structure or honeycomb, examined as a flat surface in the microscope, shows the same configuration as a fine skeleton. We can hardly see any difference between the two. We cannot accept the skeletal formation as a fundamental structure of the plasm.

As we notice very fine threads in the plasm of many cells, both in the caryoplasm of the nucleus and the cytoplasm of the cell body, the cytologist Flemming, of Kiel (1882), believed it was possible to discover them in the plasm of all cells, and based on this his filar theory of plasm. He says that we must distinguish two chemically different kinds of plasm in living matter—the filar (thread-like) and the inter-filar matter. The fine threads of the former are of different lengths, and sometimes run separately, at other times are bound in a sort of net-work (*mitoma* and *paramitoma*). In certain conditions of cell life, especially in indirect cell division, these filar formations play a great part; and also in the functions of highly differentiated cells, such as the ganglionic cells. But in many cases these plasma threads may be merely parts of a skeletal or frothy structure (honeycomb walls in section). In any case, we cannot regard the thread formation as a general elementary structure of plasm; in my opinion, it is

always a secondary phyletic product of living matter, and never a primary feature of it.

Totally different from the three preceding theories of the finer structure of the plasm is the granular theory of Altmann (1890). He supposes that all living matter is originally made up of tiny round granules, and that these independently living *bioblasts* are the real "elementary organisms," the microscopic ultimate individuals; hence the cells which are formed by the combination of these granules must be looked on as individuals of the second order. Between the granules of the granulated substance (the real active living matter) there is always an inter-granular substance; the granules are regularly distributed and arranged in these. The granules themselves, or the bioblasts, are homogeneous, sometimes globular, and sometimes oval, or of other shapes. However, the distinction between these substances is quite arbitrary, and neither chemically nor morphologically well defined. Under the head of granules Altmann throws together the most different contents of the cell—fat granules, pigment granules, secretory granules, and other products of metabolism. Hence his granular theory is now generally rejected. However, there was a sound idea at the bottom of it—namely, the idea of explaining the vital properties and functions of living matter by small separate constituents which make up the plasm, and move in a viscous medium. But these real elementary parts are not microscopically visible; they belong to the molecular world, which lies far below the limit of microscopic power. In my opinion, Altmann's visible granules, like Flemming's threads and Frommann's skeleton and Bütschli's honeycomb, are not primary structures, but secondary products of plasma differentiation.

As the special properties and activities of any natural body depend on its chemical constitution, and this is, in the long run, determined by the composition of its molecules, it is a matter of the greatest interest in biology to form as clear and distinct an idea as possible of the nature and properties of the molecules of plasm. Unfortunately, it is only possible to do this approximately, and to a slight extent. As the hypotheses of modern structural chemistry on the molecular formation of complicated organic compounds are often very unsafe, this is bound to be the case in the highest degree as regards the albuminoids and, the most important of all, the living matter or plasm. We have as yet no knowledge of the fundamental features of its very variable chemical structure. The one thing that bio-chemists have told us about it is that the molecule of plasm is very large, and made up of a great number of atoms (over a thousand); and that these are combined in smaller or larger groups, and are in a state of very unstable equilibrium, so that the life process itself causes constant changes in them.

Since the great problem of heredity was forced by Darwin in 1859 into the fore-ground of general biology, many different hypotheses and theories of it have been framed. All these have in the end to trace it to molecular features in the plasm of the germ-cells; because it is this germ-plasm of the maternal ovum and the paternal sperm-cell that conveys the characteristics of the parents to the child. Hence the great progress that has been made recently in the study of conception and heredity, by means of a number of remarkable observations and experiments, has been of service to our ideas on the molecular structure of the plasm. I have dealt with the chief of these theories in the ninth chapter of my *History of Creation*, and must refer the reader thereto.

In chronological order we have: (1) the pangenesis theory of Darwin (1868), (2) the perigenesis theory of Haeckel (1875), (3) the idioplasm theory of Nägeli (1884), (4) the germ-plasm theory of Weismann (1885), and (5) the mutation-theory of De Bries (1889). None of these attempts, and none of the later theories of heredity, has given us a satisfactory and generally admitted idea of the plasma-structure. We are not even clear as to whether in the last resort life is to be traced to the several molecules, or to groups of molecules, in the plasm. With an eye to this latter difference, we may distinguish the plastidule and micellar theories as two different groups of relevant hypotheses.

In my essay on "The Perigenesis of the Plastidules" (1875) I formulated the hypothesis that in the last instance the plastidules are the vehicles of heredity—that is to say, plasma-molecules which have the property of *memory*. In this I found support in the ingenious theory of the distinguished physiologist, Ewald Hering, who had declared in 1870 that "memory is a general property of organic matter." I do not see still how heredity can be explained without this assumption! The very word "reproduction," which is common to both processes, expresses the common character of psychic memory (as a function of the brain). By plastidules I understand simple molecules; the homogeneous nature of the plasm in the monera (both chromacea and bacteria and rhizomonera) and the primitive simplicity of their life-functions do not dispose us to think that special groups of molecules are to be distinguished in these cases. Max Verworn has recently (1903) formulated his biogen-hypothesis in the same sense, as a "critical-experimental study of the processes in the living matter." He also takes the active plasma-molecules, which he calls biogens,

as the ultimate individual factors of the life-process, and is convinced that in the simplest cases the plasm consists of homogeneous biogen-molecules.

The hypothesis of Nägeli (1884) and Weismann (1885) is totally different from the hypothesis of the plastidules and biogens as simple molecules of the plasm. According to this, the ultimate "vital unities" or individual vehicles of the life-process are not homogeneous plasma-molecules, but groups of molecules, made up of a number of different molecules. Nägeli calls them *micella*, and assigns them a crystalline structure. He supposes that these micella are combined chain-wise into micellar ropes, and that the variety of the many forms and functions of plasm is due to the different configuration and arrangement of these. Weismann says: "Life can only arise by a definite combination of different kinds of molecules, and all living matter must be made up of these groups of molecules. A single molecule cannot live, can neither assimilate nor grow nor reproduce." I do not see the justice of this observation. All the chemical and physiological properties which Weismann afterwards attributes to his hypothetical *biophora* may be ascribed to a single molecule just as well as to a group of molecules. In the simplest forms of the monera (both the chromacea and the bacteria) the nature of their rudimentary life can be explained on the one supposition just as well as the other. Naturally, this does not exclude a very complicated chemical structure in the large plastidule or biogen as a single molecule. Verworn's biogen-hypothesis seems to me quite satisfactory when it represents the primitive molecule of living matter as really the ultimate factor of life.

The chief process in the evolutionary history of the plasm is its separation into the inner nuclear matter

(caryoplasm) and the outer cellular matter (cytoplasm). When both kinds of plasm arose by differentiation from the originally simple plasm of the monera, there also took place the morphological separation of the nucleus (caryon) and cell-body (cytosoma or celleus). As these two chief forms of living matter are chemically different but nearly related, and as they may in certain circumstances (for instance, during indirect cell-division and the partial caryolysis connected therewith) enter into the closest mutual relations, we must suppose that the original severance of the two substances took place gradually and during a long period of time. It was not by a sudden bound or transformation, but by a gradual and progressive formation of the chemical antithesis of caryoplasm and cytoplasm, that the real nucleated cell (cytos) arose from the unnucleated cytode (or primitive cell). Both may correctly be comprised under the general head of *plastids* (or formative principles), as "ultimate individualities."

I regard as the chief cause of this important differentiation of the plasm the accumulation of hereditary matter—that is to say, of the internal characteristics of the plastids acquired by ancestors and transmitted to their descendants—within the plastids while their outer portion continued to maintain the intercourse with the outer world. In this way the inner nucleus became the organ of heredity and reproduction, and the outer cell-body the organ of adaptation and nutrition. I put forward this hypothesis in 1866 in my *General Morphology*: "The two functions of heredity and adaptation seem to be not yet distributed between differentiated substances in the unnucleated cytodes, but to inhere in the whole of the homogeneous mass of the plasm; while in the nucleated cell they are

divided between the two active constituents of the cell, the inner nucleus taking over the transmission of hereditary characters and the outer plasm undertaking adaptation, or the accommodation to the features of the environment." This hypothesis was afterwards (1873) confirmed by the discoveries of Strasburger, the brothers Hertwig, and others, with regard to cell-cleavage and fertilisation; it is particularly supported by the phenomena of *caryokinesis* (the movement of the nucleus) in sexual generation. Hence we can understand how it is that in the monera (chromacea and bacteria), which propagate by simple cleavage, there is no sexual generation and no nucleus.

The great significance of the nucleus in the life of the cell, as central organ of heredity, and also probably as "the soul of the cell," depends chiefly on the chemical properties of its albuminous matter, the caryoplasm. This one indispensable nuclear element is chemically akin to the cytoplasm of the cell-body, but differs from it in certain respects. The caryoplasm has a greater affinity for many colouring matters (carmine, hœmatoxylin, etc.) than the cytoplasm; and the former coagulates more quickly and firmly than the latter through acids (such as acetic and chromic acid). Hence we need only add a drop of diluted (two per cent.) acetic acid to cells that seem homogeneous to make perfectly clear the separation between the inner nucleus and outer body. As a rule, the firmer nucleus then stands out sharply as a globular or oval particle of plasm; occasionally it has other forms (cylindrical, conical, spiral, or branched). The caryoplasm seems to be originally quite homogeneous and structureless, as we find in many of the protists and many young cells of histona (especially young embryos). But in the great majority of cells the caryoplasm is

divided into two or more different substances, the chief of them being chromatin and achromin.

The most common division of the caryoplasm in the cells of the animal and plant body, and the one of chief significance for their vital activity, is that into two chemically different substances, which are usually called chromatin (or nuclein) and achromin (or linin). Chromatin has a greater affinity for colouring (*chromos*) matter (carmine, hæmatoxylin, etc.), and so this "colourable nuclear matter" is particularly regarded as the vehicle of heredity. The achromin (or achromatin, or linin) is either not at all or less easily colourable, and is akin to the cytoplasm; in direct cell-division it enters into close relations with the latter. Achromin is usually found in the form of slender threads, and hence called "nuclear thread-matter" (linin). Chromatin is generally found in roundish or rod-shaped granules (chromosomata), which exhibit very characteristic changes of form (loop formation, etc.) in indirect cell-division. The chemical, physiological, and morphological difference between chromatin and achromin must not be regarded as an original property of cell nuclei (as is wrongly stated sometimes), but is the outcome of a very early phylogenetic differentiation in the originally homogeneous caryoplasm; and this holds also of two other parts of the nucleus—the nucleolus and centrosoma.

In a good many cells, but by no means universally, we find two other constituents of the nucleus, which owe their rise to a further differentiation of the caryoplasm. The nucleolus is a small globular or oval particle, which may be found singly or in numbers in the nucleus, and behaves somewhat differently towards colouring matter than the closely related chromatin. It has a special affinity for acid aniline colours, gosin, etc. Its substance

has, therefore, been distinguished as *plastin* or *paranuclein*. The nucleolus is especially found in the tissue-cells of the higher animals and plants as an independent constituent; it is wanting in many of the unicellular protists. The same may be said of the centrosoma, or "central body" of the cell. This is an extremely small granule, on the very limit of visibility, the chemical composition of which is not known very well. We should have paid no attention to this constituent of the cell (distinguished in 1876) if it did not play an important, and perhaps leading, part in indirect cell-division. As the "polar body in the division of the nucleus," the centrosoma exercises a peculiar attraction on the granules distributed in the cytoplasm, which arrange themselves radially about this centre. The centrosomata grow independently and increase by cleavage, like the chromoplasts (chlorophyll particles, etc.). When they have split up, each of the daughter-microsomata acts in turn as a centre of attraction on its half of the cell. However, the great importance which modern cytologists have ascribed to it on this account is discounted by two circumstances. In the first place, we have not succeeded, in spite of all efforts, in discovering a centrosoma in the cells of the higher plants and many of the protists; and, in the second place, a number of recent chemical experiments have succeeded in producing centrosomata artificially (for instance, by the addition of magnesium chloride) in the cytoplasm. Hence many cytologists regard the centrosoma as a secondary product of differentiation in the cell body, not the nucleus.

Two other parts of the nucleus that we find very often, but by no means universally, in the cells of the animal and plant body are the nuclear membrane (caryotheca) and the nuclear sap (caryolymph). A large number of

cells—but not all—have the appearance of vesicles, having a thin skin enclosing a liquid content, the nuclear sap. The achromin then usually forms a framework of threads, with chromatin granules in its meshes or knots, within this round vesicle. This very thin nuclear membrane (often only visible as its contour) or caryotheca may be regarded as the result of surface-strain (at the planes of contact of caryoplasm and cytoplasm). The watery and usually clear and transparent nuclear sap (caryolymph) is formed by imbibition of watery fluid (like the frothy structure of the plasm in general). The separation of the nuclear membrane and nuclear sap is not a primary property of the nucleus, but is due to a secondary differentiation in the originally homogeneous caryoplasm.

Like the caryoplasm of the nucleus, the cytoplasm of the cell-body is originally a chemical modification of the simple and once homogeneous plasm (the archiplasm). This is clearly shown by the comparative biology of the protists, their unicellular organism presenting a much greater variety of stages of cell-organisation than the subordinate tissue-cells in the bodies of the multicellular histona. However, in the great majority of cells the cytoplasm is separated into several, and frequently very numerous, parts, which have received diverse forms and functions in the division of labour. We then see very conspicuously the regularity of cell-organisation, which is altogether wanting in the simple homogeneous plasma granules of the monera. As this great differentiation of the advanced elementary organism is incorrectly generalised by some recent cytologists and described as a universal feature of cells, it is necessary to insist explicitly that it is a secondary phylogenetic development, and is altogether wanting in the primitive organisms.

The complexity of the physiological division of labour and the accompanying morphological separation of parts is extremely great in the cytoplasm. When we wish to arrange them in a few large groups from a general point of view, we may distinguish the active plasma-formations from the passive plasma-products; the former are due to a chemical metamorphosis of the living plasm, the latter lifeless excretions from it.

Under the head of plasm-formations, or products of differentiation in the cytoplasm, we comprise all formations that are due to partial metamorphosis of the living cell-body—not lifeless excretions from it, but living parts of its substance, undertaking special functions, and therefore chemically and morphologically differentiated from the primary cytoplasm. One of the commonest differentiations of this kind is the separation of the firm hyaline skin-layer (hyaloplasm) from the softer granular marrow-layer (polioplasm); though the two often pass into each other without clear limits. In most plant-cells special granules of plasm, mostly globular or roundish, are developed, called *trophoplasts*, and these undertake the work of metabolism. To this class belong the amyloplasts, which produce starch (amylum), the chloroplasts or chlorophyll-granules which form the green matter (chlorophyll) in the leaf, and the chromoplasts which form colour-crystals of various sorts. In the cells of the higher animals the myoplasts form the special contractile tissue of the muscles, and the neuroplasts the psychic tissue of the nerve-matter. On the other hand, the distinction between the body-plasm (somoplasma) and the germ-plasm (germoplasma), which serves as the base of Weismann's untenable theory of the germ-plasm (*cf.* chap. xvi.), is purely hypothetical and without direct observation to support it.

The infinite variety of parts of the cell which arise as excretions of the living active cytoplasm, and so must be regarded as lifeless plasma-products, may be divided into two chief groups—internal and external. The former are stored within the living cytoplasm, the latter thrust out from it.

Internal plasma-products of common occurrence are the microsomata, very small and opaque particles which are generally regarded as products of metabolism. They consist sometimes of fat, sometimes of derivatives of albumin, sometimes of other substances of which we do not know the chemical composition. The same may be said of the large and variously-coloured pigment-granules, which are very common and determine the colour of tissues. Also very common in the cytoplasm are large accumulations of fat in the shape of oil-globules, fat-crystals, etc., besides other crystals of a very different sort, partly organic crystals (for instance, albuminous crystals in the aleuron-granules of plants), partly inorganic crystals (for instance, of oxalic acid salts in many plant-cells, of calcareous salts in many animal-cells). The watery cell-sap (cytolymph) plays an important part in many of the larger cells. It is formed by the accumulation of fluid in the cytoplasm, and is found in its frothy structure. The large empty spaces which it forms are called vacuoles, with very regularly disposed alveoles. When the cell-sap gathers in great abundance within the cell, we get the large vesicular cells which are found in the tissues of the higher plants, the cartilages, etc.

As external excretions of the living cytoplasm that have acquired some importance, especially as protective organs, in the majority of cells, we have first of all the cell-membranes, the firm capsules or protective skins

which enclose the soft cell-body, like a snail in its house. In the first period of the cell-theory (1838–1859) such an integument was ascribed to all cells, and often regarded as their chief constituent; but it was discovered afterwards that this protective skin is altogether wanting in many (especially animal) cells, and that it is not found in many when they are young, but grows subsequently. We now distinguish between naked cells (gymnocytes) and covered cells (thecocytes). As examples of naked cells we have the amœbæ, and many of the infusoria, the spores of algæ, the spermatozoa, and many animal tissue-cells.

The cell-covering (cytotheca) varies very much in size, shape, composition, and chemical character, especially in the rhizopods among the unicellular protists. The flint shells of the radiolaria and diatomes, the chalky cells of the thalamophora and calcocytea, the cellulose shells of the desmidiacea and syphonea, show the extraordinary plasticity of the constructive cytoplasm (*cf.* chap. viii.). Among the histona the tissue-plants are remarkable for the infinite variety of shape and differentiation of their cellulose capsules. The familiar properties of wood, cork, bast, the hard shells of fruit, etc., are due to the manifold chemical modification and morphological differentiation which the cellulose membrane undergoes in the tissues of plants. This is less frequently seen in the tissues of animals; but, on the other hand, the intercellular and the cuticular matter play a greater part in these.

The intercellular matter, an important external plasma-product, is formed by the social cells in the tissues of the histona thrusting out in common firm protective membranes. These protective structures are very common among communities of protists, in the

form of masses of jelly, in which a number of cells of the same kind are united; such are the zooglœa of many of the bacteria and chromacea, the common jelly-like envelope of the volvocina and many diatomes, and the globular cell-communities of the polycyttaria (or social radiolaria). The chief part is played by intercellular matter in the body of the higher animals, in the form of mesenchyma-tissue; the connecting tissue, cartilages, and bones owe their peculiar property to the amount and quality of the intercellular matter that is deposited between the social cells.

When the socially-joined epidermic cells at the surface of the tissue-body thrust forth in common a protective covering, we get the cuticles, which are often thick and solid armour-plates. In many of the metaphyta wax and flinty matter are deposited in the cellulose cuticles. The strongest formation is found in the invertebrate animals, where the cuticle often determines the whole shape and articulation, as in the calcareous shells of molluscs (mussel-shells, snail-shells, cockle-shells, etc.); and especially the coats of the articulata (the crab's coat of mail, and the skins of spiders and insects).

## Chapter VII.

# UNITIES OF LIFE

**Units of life. Simple and complex organisms. Morphological and physiological individuals. Morphonta and bionta. Stages of individuality: cell, person, stem. Actual and virtual bionta. Partial and genealogical bionta. Metaphysical individuals. Cells (elementary organisms). Cell membranes. Unnucleated cells. Plastids (cytodes and cells). Primitive cells and nucleated cells. Organella (cell organs). Cell communities (cœnobia). Tissues of histona. Systems of organs. Organic apparatus. Histonal individuals (sprouts and persons). Articulation of the histona (metamerism). Stems of the histona. Animal states.**

The dissection of the body of the higher animal and plant into its various organs soon prompted comparative anatomists to draw a distinction between simple and complex organisms. Then, when the cell-theory developed in the course of the last half-century, the common anatomic ground-work of all living forms was recognised in the cell; and the conception of the cell as the elementary organism led to the further belief that our own frame, like that of all the higher animals and plants, is a cell-state, composed of millions of microscopic citizens, the individual cells, which work more or less independently therein, and co-operate for the common purposes of the entire community. This fundamental principle of the modern cell-theory was applied with great success by Rudolph Virchow to the diseased organism, and led to most important reforms in medicine. The cells are, in his view, independent "life-unities or

individual life-centres," and the unified life of the whole man is the combined result of the work of his component cells. In this way the cells are the real life-unities of the organism. Their individual independence is at once seen in the permanently unicellular protists, of which several thousand species are already known to us.

On the other hand, we find among the lower animals and the higher plants a composition of homogeneous parts, which represents a higher stage of life-unity. The tree is an individual, but it is made up of a number of branches or individual sprouts, each of which consists in like manner of an axial stem with leaves attached. If we detach such a branch and plant it in the ground, it takes root and grows into an independent plant. So the coral-stem is made up of a number of individual animals or persons, each of which has its own stomach and mouth with a crown of tentacles. Each several coral-individual is equivalent to a single living polyp (actinia). Thus the stem *(cormus)* is a higher unity, both in the animal and the plant world. Even the herds of gregarious animals, the swarms of bees and ants, and the communities of human beings, are similar unities; with the difference that the individual persons or citizens are not physically connected, but held together by common interests. We can, therefore, distinguish three stages of organic individuality, one building upon the other—the cell, the person (or sprout), and the stem or state (cormus). Each higher unity represents an intimate union of lower individuals. Morphologically, in relation to their anatomic structure, the latter are independent; but physiologically, in respect of the life-unity of the whole, they are subordinated to the former.

This relation is quite clear in the familiar examples I have quoted. But there are other organisms in which

this is not so, and where the question of the real individuality is very difficult to answer. Thus, fifty years ago, we came to recognise floating animal-stems in the remarkable siphonophora, or social medusæ, which had hitherto been regarded as individual animals, or medusæ with a multiplicity of organs; further study proved that each of these apparent organs is really a modified medusa, and the whole united structure a stem. This example throws a good deal of light on the important question of association and division of labour. The whole floating siphonophoron is, physiologically considered (in respect of its vital activity), a harmoniously-organised animal with a number of different organs; but from the morphological point of view (in respect of form and structure) each dependent organ is really an independent medusa.

It is clear, from these few illustrations, that the question of organic individuality is by no means so simple as it seems at first sight, and that it receives different answers according as we look at the form and structure (morphologically) or the vital and psychic activity (physiologically). We must, therefore, distinguish at once between morphological *(morphonta)* and physiological *(bionta)* individuals. The tree and the siphonophoron are bionta, or individuals of the highest order, made up of a number of similar branches or persons, the social morphonta. But, when we further dissect the latter anatomically into their various organs, and these again into their microscopic elements, the cells, each branch or person seems to be a bion, and their cells to be morphonta. Each multicellular organism is, however, developed in the beginning from a single cell, the stem-cell (cytula) or fertilised ovum; this is at once a morphon and a bion, a simple individual both

morphologically and physiologically. The whole process of its development into a multicellular organism consists in a repeated cleavage of the stem-cell, the resultant cells being joined in a higher unity, and assuming different forms in consequence of the division of work.

The complicated modern State, with its remarkable achievements, may be regarded as the highest stage of individual perfection which is known to us in organic nature. But we can only understand the structure of this extremely complex "organism of the highest order," and its social forms and functions, when we have a sociological knowledge of the various classes that compose it, and the laws of their association and division of labour; and when we have made an anthropological study of the nature of the persons who have united, under the same laws, for the formation of a community and are distributed in its various classes. The familiar arrangement of these classes, and the settling of the rank in the mass and the governing body, show us how this complex social organism is built up step by step.

But we have to look in the same way on the cell-state, which is made up from the separate individualities in human society or in the kingdom of the tissue-animals, or the branches in the kingdom of the tissue-plants. Their complex organism, composed of various organs and tissues, can only be understood when we are acquainted with their constituent elements, the cells, and the laws according to which these elementary organisms unite to form cell-communities and tissues, and are in turn modified in the divers organs in the division of labour. We must, therefore, first establish the scale of the morphonta, and the laws of their association and ergonomy, according to which the several stages or conditions of morphological individuality build on each

other. Three such stages may be at once distinguished : (1) the cell (or, more correctly, the plastid) ; (2) the person (animal) or branch (vegetal) ; and (3) the stem or cormus. But we shall find that there are further subordinate stages under each of these three. It is only in the case of the protists that the morphological unity is bound up with the physiological. In the case of the histona, the multicellular, tissue-forming organisms, this is only so at the beginning of individual existence (at the stage of the stem-cell). As soon as the multicellular body arises from this cytula by repeated segmentation, it is raised to the stage of a higher individuality, the cell-state.

Our own human frame is, in its mature condition, like that of all the higher animals, a very complete cell-state, but a single cell at the beginning of its existence. We speak of the life-unity of the former as an actual bion, and that of the latter as a virtual bion ; in other words, the physiological individual or the life-unity has in the first case reached the highest stage of individual development that pertains to its species, while in the second case it remains at the lowest stage of virtual formation, and has only the capacity of rising to the higher stage. In the higher plants and animals only one cell of the organism, or the two combined sexual cells (ovum and spermium), are the potential bion which may develop into an actual one. There are, however, exceptions. In the fresh-water polyp (hydra) and cognate cnidaria each piece of the body-wall, in the bath-sponge (euspongia) and similar sponges each piece of tissue, and in many plants (for instance, marchantia among the crytogams and bryophyllum among the phanerogams) each portion of a branch or leaf, has the power to develop into a mature organism, and is, therefore, a virtual bion.

From these virtual bionta (parts of the body that may grow into whole organisms) we must distinguish the partial bionta which have not this property. These are separated parts of the body that live for a time after being cut off from the whole organism, but then die off. Thus, for instance, the heart of a tortoise beats for a long time after being cut out. A flower that has been plucked may, if put in water, keep fresh and alive for many days. In some highly organised cephalopods one of the eight arms of the male developes into an independent body, swims about, and accomplishes the fertilisation of the female (*hectocotylus* among the *argonauta*, *philonexis*, etc.). It was at first thought to be an independent animal parasite. The same thing happened with the remarkable fold-like dorsal appendages of a large naked snail (*thetys*), which get detached and creep about. The body of many of the lower animals may be cut in pieces, and yet may live for weeks. The life-properties of these partial bionta are important in view of the general question of the nature of life and its apparent unity in most of the higher organisms. As a fact, even here the cells and organs lead their separate individual life, though they are subordinate to and dependent on the whole.

It has been attempted to answer this question of organic individuality in the sense of counting all organisms individuals which develop from a single fertilised ovum. Thus, the Italian botanist Gallesio, in 1816, regarded all plants that arise by asexual generation (budding or segmentation)—sprouts, branches, slips, bulbs, etc.—as merely portions of a single individual that came from an egg (the seed). So also Huxley, in 1855, considered the sum of all the animals that have been produced by asexual propagation, but from a single

sexually generated animal, to be parts of one individual. In practice, however, this principle is useless. We should have to say that the millions of plant-lice which arise parthenogenetically from unfertilised germ-cells, but are originally descended from one impregnated ovum, are one single individual; so also all the weeping-willows in Europe, because they all came from shoots of one single sexually-produced tree.

Many attempts have been made in the course of the nineteenth century to give a generally satisfactory answer to this difficult question of the content and connotation of the idea of the organic individual. None of these has found general favour. I have compared and criticised them in the third book of my *General Morphology*. I there paid special attention to the views of Goethe, Alexander Braun, and Nägeli among the botanists, and Johannes Müller, Leuckart, and Victor Carus among the zoologists. When we consider the striking divergence of the views of such distinguished scientists and thinkers on so important a biological question, we can understand that opinions are still very divided to-day. Hence we must not be too hard on the metaphysical philosophers when—in complete ignorance of the real facts—they rear the most extraordinary theories in their airy speculations on "the principle of individuation." Compare, for instance, the opinions of the school-men and those of recent thinkers such as Arthur Schopenhauer and Edward Hartmann. As a rule, the psychological side of the problem—the question of the individual soul—is very prominent, without much attention being paid to its material substratum—the anatomic basis of the organism. Many metaphysicians, who, in their one-sided anthropism, make man here also the measure of all things, would assign personal consciousness as the basis of the idea of

individuality. It is obvious that this is not a practicable test even for the higher animals, to say nothing of the lower animals and plants. In these we have a far greater variety of individuality on the one hand, and a far greater simplicity of construction on the other. I have tried to show, in my essay on *The Individuality of the Animal Body* (1878), the easiest way to answer these complicated tectological questions, and to support it by the science of structure. It suffices to distinguish the three chief stages I have mentioned, and to explain clearly their physiological significance on the one hand and morphological on the other. We will therefore consider the cell first, then the person (or sprout), and, finally, the stock (or cormus).

Ever since the middle of the nineteenth century the cell theory has been generally and rightly considered one of the most important theories in biology. Every anatomical, histological, physiological, and ontogenetic work must build on the idea of the cell as the elementary organism. Nevertheless, we are still very far from having a general and clear agreement as to this universal and fundamental idea. On the contrary, the ablest biologists still differ considerably as to the nature of the cell or the elementary individual, its relation to the whole of the multicellular organism, and so on. This divergence of views is partly due to the intricacy of the phenomena we find in the life of the cell, and partly to the many and extensive changes that have been made in the meaning of the term in the course of its employment. Let us first cast a glance at the various stages of its history.

When in the last third of the seventeenth century a number of scientists, especially Malpighi in Italy and Crew in England, used the microscope for the first time

in the anatomic study of plant structure, they noticed a certain build of the tissue that closely resembled the honeycomb. The closely packed wax cells, filled with honey, of the hive, which show a hexagonal appearance in section, are like the wood cells that contain the sap in the plant. It was the great merit of Schleiden, the real founder of the cell theory, to prove that *all* the different tissues of plants are originally composed of such cells (1838). Theodor Schwann soon afterwards proved the same for the animal tissues; in 1839 he extended the theory to the whole organic world. Both these scientists regarded the cell as essentially a vesicle, the firm membrane of which enclosed a fluid content, and a solid smaller body inside this, which R. Brown had recognised as the nucleus in 1833. They compared the cell, as a microscopic individual, to an organic crystal, and thought it arose by a sort of crystallisation in an organic medium (cytoblastema); in this the central nucleus would serve as starting point like the nucleus of the crystal.

In the first twenty years (1839–59) of the cell theory it was a fixed principle that there were three essential parts of the cell. Firstly, there was the strong outer membrane, which was not only regarded as a protective covering, but also credited with a great deal of importance as an element in the building of the organism. In the second place, there was the fluid or semi-fluid content (the sap); and, thirdly, the firm nucleus enclosed in the sap. In order to give a clearer idea of the relative thickness and disposition of these parts, the cell was compared to a cherry or a plum. The soft flesh of this fruit (corresponding to the cell sap) can, with difficulty, be separated from the external firm skin or from the hard stone within. A great step in advance was made in 1860, when Max Schultze showed that the

external membrane was an unessential and secondarily formed part of the cell. It is, as a fact, altogether wanting in many, especially young, cells of the animal body. They are naked cells without any membrane. The distinguished anatomist also proved that the so-called "cell sap"—the real body of the cell—is not a simple fluid, but a viscous, albuminous substance, the independent movements of which had long been known in the rhizopods, and which the first to study it carefully, Felix Dujardin, had described as *sarcode* in 1835. Max Schultze further showed that this "sarcode" was identical with the "cell mucus" of the plant cells which Hugo Mohl had designated "protoplasm" in 1846, and that this living matter must be regarded as the real vehicle of the phenomena of life. As the membrane was now recognised to be non-essential, of secondary growth, and completely wanting in some cases, there remained only two essential parts of the cell—the outer soft cell body, consisting of protoplasm, and the inner firm nucleus, consisting of a similar substance called nuclein. The original naked cell was now like a cherry or plum without the skin. This new idea of the cell, formulated forty years ago, which I endeavoured to confirm in my monograph on the radiolaria (1862), is now generally accepted, and the cell is defined as a granule or particle of protoplasm (= cytoplasm) enclosing a firm and definite nucleus (or caryon, consisting of caryoplasm).

This would be a good occasion to glance at the errors to which microscopic investigation and the conclusions based on it are liable. Although Kölliker in 1845, and Remak in 1851, had drawn attention to the existence of naked cells, and had compared their movements (for instance, in lymph cells) to those of the protoplasm in

plant-cells, the majority of the leading microscopists clung for twenty years to the dogma that every cell must have a membrane; the definite outline which even a naked cell must show in a different refracting medium was taken to be the sign of a special and anatomically separable membrane. It would be just as correct to talk of a protective membrane on a homogeneous glass ball; its outline is sharply defined. In the long controversy that "exact" observers sustained as to the presence or absence of a membrane, this optical error—the false interpretation of a sharp contour—counted for a good deal. It is much the same with other conflicts of "exact" observers who give their "certain observations" as facts, whereas they are really inferences from imperfect observations on which different interpretations may be put.

Forty years ago (1864) I tried in vain to detect a nucleus in the naked, living, mobile protoplasm of a few small rhizopod-like protists (protamœba and protogenes). Other observers, who afterwards studied similar unnucleated cells (Gruber, Cienkowski, and others), were no more successful. On the ground of these observations, which were often repeated afterwards, I formed the class of the *monera*—the simplest unnucleated organisms—in my *General Morphology* in 1866, and pointed out their great importance in solving some of the chief problems of biology. This importance has been much enhanced of late, since the chromacea and bacteria have also been recognised as unnucleated cells. Bütschli has, it is true, raised the objection that their homogeneous plasma-body behaves, not as cytoplasm, but as caryoplasm (or nuclein), and so that these simplest plastids correspond, not to the cell-body, but to the nucleus, of other cells. On this view the bacteria and chromacea are not cells

without nuclei, but nuclei without cell-bodies. This idea agrees with my own in conceiving the plasma-body of the monera (apart from its molecular structure) as homogeneous and not yet advanced as far as the characteristic differentiation of inner nucleus and outer cell-body. Bearing in mind that these essential parts of the cell (in the view of most cytologists) are chemically related yet different from each other, we have three possible cases of the original formation of the nucleated cell from the unnucleated cytode: (1) The nucleus and cell-body have arisen by differentiation of a homogeneous plasm (monera); (2) the cell-body is a secondary growth from the primary nucleus; (3) the nucleus is a secondary development from the cell-body.

On the first view, which I hold, the plasm, or living matter, of the earliest organisms on the earth (which can only be conceived as archigonous monera) was a homogeneous *plasson* or archiplasm—that is to say, a plasma-compound that was not yet differentiated into outer cytoplasm and inner caryoplasm. The rise of this chemical distinction—and the accompanying morphological division of cell-body and nucleus—was due to a phyletic differentiation; it was the outcome of a very early and most important division of labour. The hereditary matter gathered in the nucleus, the outer cell-matter controlling the intercourse with the external world. Thus, by this first ergonomy, the nucleus became the vehicle of heredity and the cell-body the organ of adaptation. Opposed to this view is the second, the hypothesis which the founder of the cell-theory, Schleiden, had put forward—that the nucleus is the original base of the cell, and the cell-body a secondary development from it. This opinion (which, in the main, corresponds to that of Bütschli) raises a number of

difficulties; as does also the third hypothesis, that the unnucleated "protoplasm-body" (the outer cytoplasm-body) is the original formation, and that the nucleus arose secondarily by condensation and chemical modification of it. At the bottom, however, the difference between the three hypotheses on the primary cytogenesis is not as great as it seems at first sight. However, I am more inclined to adhere to the first; it supposes that the physiological and chemical differences between nucleus and cell-body, which afterwards became so important, were not originally present. The phenomena of caryolysis in indirect cell-division show us still how close are the relations of the two substances.

If the organic population of our planet has arisen naturally, and not by a miracle, as Reinke and other vitalists suppose, the earliest elementary organisms, produced by the chemical process of archigony (spontaneous generation), could not be real nucleated cells, but unnucleated cytodes of the type of the chromacea (*cf.* chap. ii.). The nucleated real cell, as Oscar Hertwig and others define it to-day, can only have arisen by phylogenetic differentiation of nucleus and cell-body from the simple cytode of the monera. In that case it is a matter of simple logic to distinguish the older cytode from the later cell. The two may then best be comprised (as I proposed in vain in 1866) under the name of "plastids" (formative principles)—that is, the elementary organism in the broader sense. But if it is preferred to call the latter *cells* (in the broader sense), the wrong modern idea of the cell must be altered, and the nucleus-feature omitted from it. The cell is then simply the living particle of plasm, and its two stages of development must be described by other names. The unnucleated plastid might be called *primitive cell*

(protocytos), and the ordinary nucleated one the nuclear cell (caryocytos).

A long gradation of cellular organisation leads from the simplest primitive cells (monera) to the highest developed protists. While no morphological organisation whatever is discoverable in the homogeneous plasma-body of the chromacea and bacteria, we find a composition from different parts in the highly-differentiated body of the advanced protophyta (diatomes, siphonea) and protozoa (radiolaria, infusoria). The manifold parts of the unicellular organism, developed by division of work in the plasm, discharge various functions, and behave physiologically like the organs of the multicellular histona. But as the idea of "organ" in the latter is morphologically fixed as a multicellular part of the body, made up of numerous tissues, we cannot call these similarly functioning parts "organs of the cell," and had better describe them as organella (or organoids).

The great majority of the protists are, in the developed condition, as actual individuals, equivalent morphologically to real nucleated cells. By means of adaptation to the most varied conditions and the inheritance of the properties thus acquired such a variety of unicellular forms has been evolved in the course of millions of years that we can distinguish thousands of living species, both of plasmodomous protophyta and plasmophagous protozoa. The number of known and named species is already as high as this in several distinct classes, as, for instance, in the diatomes of the primitive plants and the radiolaria of the primitive animals. These solitary living unicellulars, or "hermit-cells," may be called *monobia*.

Many other protists have abandoned this original solitary life; they follow their social instincts and form

communities or colonies of cells (*cœnobia*). These are usually formed by the daughter-cells which arise from the cleavage of a mother-cell remaining united after the division, and so on with the succeeding generations which come from their repeated segmentation. The following are the chief forms of these cœnobia :—

1. Gelatinous Cœnobia.—The social cells secrete a structureless mass of jelly, and remained associated in the common gelatinous mass, without actual contact. Sometimes they are regularly, at other times irregularly, distributed in it. We find cœnobia of this kind even among the monera, such as the *zooglœa* of many bacteria and chromacea. They are common among the protophyta and protozoa.

2. Spherical Cœnobia.—The cell-community forms a sort of ball, the cells lying close together at its surface, touching each other or even forming a continuous layer ; such are *holosphœra* and *volvox* among the protophyta, *magosphœra* and *synura* among the protozoa. The latter are particularly interesting because they resemble the *blastula*, an important embryological stage of the metazoa, of which the simple, epithelial cell-layer at the surface of the hollow sphere is called the *blastoderm* (or germinal membrane).

3. Arboreal Cœnobia.—The cell-community takes the form of a small tree or shrub, the fixed cells secreting jelly-like stalks at their base and these forming branches. At the top of each stalk or branch is an independent cell ; so in the case of the *gomphonema* and many other diatomes, the *codonocladium* among the flagellata, and the *carchesium* among the ciliata.

4. Catenal Cœnobia.—The cell-community forms a chain, the links of which (the individual cells) are joined in a row. We find chain-like cell-communities of this

sort, or "articulated threads," even among the monera (*oscillaria* and *nostic* among the chromacea, *leptothrix* among the bacteria). Among the diatomes we have the *bacillaria*, among the thalamophora *nodosaria*, as examples. Many of the lower protophyta (algaria and algetta) form the direct transition to the true algæ among the metaphyta, as the thread-like layer of the latter (for instance, *cladophora*) is only a higher development of the catenal cœnobium, with polymorphism of the co-ordinated cells. We may also regard these articulated multicellular threads as the first sketch for the formation of tissues in the metaphyta.

The stable communities of cells which make up the body of the histona, or multicellular plants and animals, are called tissues (*tela* or *hista*). They differ from the cœnobia of the protists in that the social cells give up their independence, assume different forms in the division of labour, and subordinate themselves to the higher unity of the organ. However, it would be just as difficult to lay down a sharp limit between the cœnobia and the tissues as between the protists and the histona which possess them; the latter have been developed phylogenetically from the former. The original physiological independence of the cells which have combined to form tissues is more completely lost in proportion to the closeness of their combination, the complexity of their division of labour, and the differentiation and centralisation of the tissue-organism. Hence the various kinds of tissue in the body of the histona behave like the various classes and professions in a state. The higher the civilisation and the more varied the classes of workers, the more they are dependent on each other, and the state is centralised.

In the lower tissue-forming plants, the algæ and fungi,

the plant-body has the appearance of a layer of cells, the tissues of which show little or no division of labour. In these *thallophyta* there are none of the conducting or vascular fibres, the formation of which is of great importance in the higher plants in connection with their physiological function of circulation of the sap. These more advanced vascular plants comprehend the two great groups of ferns (*pteridophyta*) and flowering plants (*anthophyta*, or phanerogams). Their body is always composed of two chief organs, the axial stem and the lateral leaves. This is also the case with the mosses (*bryophyta*), which have no vascular fibres; they lie between the two chief groups of the non-vascular thallophyta and the vascular cormophyta. However, this histological and organological division of the two great groups of tissue-plants must not be pressed; there are many exceptions and intermediate forms. In general their manifold tissue-forms may be brought under two chief groups, which we may call primary and secondary. The primary tissues are the phylogenetically older and histologically simple "cell-tissues," such as we have in the thallophyta (algæ, fungi, and mosses); in these there are no conducting fibres, or, at least, only rudimentary ones. The secondary tissues are a later development from these; they form conducting and vascular fibres and other highly differentiated forms of tissue (cambium, wood, etc.). They make up the bodies of the more complex vascular plants, the ferns and flowering plants.

In the bodies of the tissue-animals we may similarly distinguish two chief groups of tissues, the primary and secondary. The former are phylogenetically and ontogenetically older than the latter. The primary tissues of the metazoa are the *epitelia*, simple layers of cells or forms of tissue directly derived

from such (glands, etc.). Secondary tissues, evolved from the former by physiological change of work and morphological differentiation, are the *apotelia;* of these "derivative tissues" we may distinguish the three leading groups of connective tissue, muscular tissue, and nerve tissue. These three great groups of tissue in the animal world may be sub-divided, like the plant groups, into lower and higher sub-sections. The cœlenteria (gastræads, sponges, cnidaria) are predominantly built up of epitelia, as are also the phyletically older group of the cœlomaria; in the vast majority of the latter, however, the great mass of the body is formed of apotelia, and they are subject to the most extensive differentiation. The embryo of all the metazoa consists solely of epitelia (the germ-layers) at first; apotelia are developed from these afterwards by differentiation of the tissues.

Comparative anatomy distinguishes in the multicellular body of the tissue-forming organisms a great number of different parts, which are regularly adapted to discharge definite vital functions, and have been most intricately developed in virtue of the division of labour. They are called "organs" in the stricter sense, in opposition to the organella (or organoids) of the protists; the latter have, it is true, a similar physiological purport, but are not (being parts of a cell) equal to the former morphologically. The remarkable efficiency that we find in the structure of the various organs in view of the functions they have to discharge, and the regularity of their construction in the unity of the histon—in other words, their adaptive organisation—is explained mechanically by the theory of selection, while the teleological hypotheses of dualistic biology (for instance, the "intelligent dominants" of Reinke) completely fail to account for their origin. The gradual advance of the organs and their physiological

division of labour have many analogies in the two kingdoms of the histona. While at the lowest stages the simple organ represents only a separate individual piece of primitive tissue, we find special systems of organs and organic apparatus in the higher stages.

The idea of a particular system of organs is determined by the unity of one tissue which forms the characteristic element in the totality of the organs that belong to it. Of such systems in the kingdom of the metaphyta we have: the skin-system (with the tissue of the epidermis), the vascular system (with its conducting and vascular fibres), and the complementary tissue system (with the basic tissue). In the kingdom of the metazoa we may similarly distinguish: the skin-system (integument of the epidermis), the vascular system (with the mesenchyma-tissue of the blood and blood-vessels), the muscular system (with the muscle-tissue), and the nervous system (with the neurona of the nerve-tissue).

In contrast with the histological idea of a system of organs, we have the physiological conception of an apparatus of organs. This is not determined by the unity of the constituent tissue, but by the unity of the life-work that is accomplished by the particular group of organs in the histona. Such an apparatus of organs is, for instance, the flowers and the fruit developing therefrom in the phanerogams, or the eye or the gut of an animal. In these apparatus the most diverse organs and systems of organs may be associated for the fulfilment of a definite physiological task.

In the higher animals and plants we usually regard as the "real individual" (in the wider sense of the word) the tissue-forming organism made up of various organs; and we may here briefly and instructively call this the histonal individual (or, more briefly, the "histonal").

Botanists call this individual phenomenon among the metaphyta a sprout (*blastus*). Zoologists give the title of "person" (*prosopon*) to the corresponding unity among the animals. The two forms agree very much in their general features, and may be called "individuals of the second order," if we take the cells to be the first and the stock the third stage in the hierarchy of organic individuality. In comprising them here under the general head of histonals, or histonal individuals, I mean by this to designate the definite physiological unity of the multicellular and tissue-forming organism, as contrasted with the unicellular protist on the one hand, and the higher stem, made up of several histonals, on the other.

The plant-histonal, which Alexander Braun especially clearly marked out and described as the sprout, is found in two principal forms in the kingdom of the metaphyta—the lower form of the layer-sprout (*thallus*) and the higher form of the stalk-sprout (*culmus*). The thallus predominates in the lower and older sub-kingdom of the layer-plants (*thallophyta*), in the classes of the algæ and fungi; the culmus in the higher and younger sub-kingdom of the stalk-plants (*cormophyta*), in the classes of the mosses, ferns, and flowering plants. The culmus presents in general the characteristic form of an axial central organ, the stalk, with lateral organs, the leaves, attached to this at the sides, the former having an unlimited vertical growth and the latter an unlimited basal growth. The thallus does not yet show this important morphological division. There are, however, exceptions in both groups of the metaphyta. The large and highly developed *fucoidea* among the algæ exhibit similar differentiations of organs to those we distinguish as stalk and leaves in the higher cormophyta. On the other hand, they are

wanting in the lower liver-worts, which form a thallus like many of the algæ; thus, for instance, the liver-wort *riccia fluitans* is just like the brown alga *dictyota dichotoma*. Other primitive liver-worts (such as the *anthoceros*) have also a very simple thallus; but most of them have a separation of the thallus into an axial organ (stalk) and several lateral organs (leaves). In the distribution of labour among the leaves there then emerge the differences between the lower leaves, foliage leaves, higher leaves, and flower leaves. A simple poppy-plant *(papaver)* or a single-flowered *gentiana ciliata*, which has only one bloom at the top of its branchless stalk, is a good example of a highly developed culmus.

To the plant-sprout corresponds in the animal world the *person*. All the tissue-animals pass in the course of their embryonic development through the important stage of the *gastrula*, or "cup-shaped embryo." The whole body of the tissue-animal at this stage forms at first a simple gut-sac or gastric sac (the primitive gut), the cavity of which opens outwards by a primitive mouth. The thin wall of the sac is formed by two superimposed layers of cells, the two primary germinal layers. This gastrula is the simplest form of the "person," and the two germinal layers are its sole organs.

The diverse animal-forms which develop along different lines from this common embryonic form of the gastrula may be grouped into two sub-kingdoms, the lower (*cœlenteria*) and the upper (*cœlomaria*) animals. The former correspond in the simplicity of their structure in many respects to the thallophyta, and the latter to the cormophyta. Of the four stems of the cœlenteria (which have only a ventral opening and no gut-cavity) the gastræads remain at the gastrula stage, and the sponges are formed by multiplication of the same stems of

gastræads. On the other hand, the cnidaria develop into higher radial (star-shaped) persons, and the platodes into lower bilateral persons. From the latter are derived the worms (*vermalia*), the common stem-groups of the five higher animal stems, the unarticulated molluscs, echinoderms, and tunicates, and the limb-forming articulates and vertebrates.

A large part of the physiological advantages and morphological perfection which the higher histona have, as contrasted with the lower, may be traced to the circumstance that the tissue-forming organism articulates—that is to say, divides on its long axis into several sections. With this multiplication of groups of organs there goes, as a rule, a more or less extensive division of work among them, a leading factor of higher development. In this point also we see the biogenetic parallelism between the two great groups of the tissue-plants and tissue-animals.

In the kingdom of the tissue-plants the articulated cormophyta rise high above the unarticulated thallophyta. While the articulation of the stem of the former proceeds and leaves are developed at the knots (*nodi*) between each two sections of the stalk, far greater play is offered to polymorphic differentiation than in the thallophyta, which are generally without this metamerism. The formation of the bloom in the flowering plants or phanerogams consists in a sexual division of labour among the thickly-gathered leaves in a short section of a stem.

To the two groups of unarticulated and articulated sprouts in the kingdom of the tissue-plants correspond, in many respects, the two sections of the tissue-animals, the unarticulated and the articulate. The two stems of the articulates and vertebrates rise above all the other metazoa by the perfection of their organism and the

variety of their functions. In the articulates the metamerism is chiefly external—an articulation of the body wall. In the vertebrates it mainly affects the internal organs, the skeleton and the muscular system. The vertebration (articulation) of the vertebrates is not outwardly visible like that of the articulates. In both stems the articulation is similar in the lower and upper forms, as we find in the annelids and myriapods, the acrania and cyclostoma. On the other hand, the higher the organisation, the greater is the unlikeness of the members or articulated parts, as in the arachnida and insects, the amphibia and amniotes. The same antithesis is found in the lower and higher crustacea. This metamerism of the higher metazoa is of a motor character, having been acquired through the manner of movement of the lengthened body; but we find in some groups of the lower, and usually unarticulated, metazoa a propagative metamerism, determined by budding at the end; such is the strobilation of the chain-worms and the scyphostoma polyps. The individual metamera (parts) that are released from the end of the chain in these cases immediately show their individuality. This is also the case with many of the annelids, in which every member that is separated has the power to reproduce the whole chain of metamera.

The third and highest stage of individuality to which the multicellular organism attains is the stock or colony *(cormus)*. It is usually formed by a permanent association of histonals that are produced by cleavage (imperfect segmentation or budding) from one histonal individual. The great majority of the metaphyta form complex plants in this sense. But among the metazoa we find this form of individuality only in the lower (and generally stationary) stages of development. Here also

there is a striking parallelism of development between the two chief groups of the histona. At the lower stages of stock-formation there is equality of the social histonals. But in the higher grades they become unequally developed in the division of labour; and the greater the differences between them become, the greater is the centralisation of the whole stock (as in the case of the siphonophora). We may therefore distinguish two principal forms of stocks—the homonomous and heteronomous, the one without, and the other with, division of labour among the histonals.

The history of civilisation teaches us that its gradual evolution is bound up with three different processes: (1) Association of individuals in a community; (2) division of labour (ergonomy) among the social elements, and a consequent differentiation of structure (polymorphism); (3) centralisation or integration of the unified whole, or rigid organisation of the community. The same fundamental laws of sociology hold good for association throughout the entire organic world; and also for the gradual evolution of the several organs out of the tissues and cell-communities. The formation of human societies is directly connected with the gregariousness of the nearest related mammals. The herds of apes and ungulates, the packs of wolves, the flocks of birds, often controlled by a single leader, exhibit various stages of social formation; as also the swarms of the higher articulates (insects, crustacea), especially communities of ants and termites, swarms of bees, etc. These organised communities of free individuals are distinguished from the stationary colonies of the lower animals chiefly by the circumstance that the social elements are not bodily connected, but held together by the ideal link of common interest.

## Chapter VIII.

# FORMS OF LIFE

Morphology. Laws of symmetry. Fundamental forms of animals and plants. Fundamental forms of protists and histona. Four chief classes of fundamental forms: (1) Centrostigma: vesicles (smooth vesicle and tabular vesicle); (2) Centraxonia: typical forms with central axis. Uniaxial (monaxonia, equipolar and un-equipolar). Transverse-axial (stauraxonia, double-pyramidal and pyramidal); (3) Centroplana: fundamental forms with central plane. Bilateral symmetry. Bilateral-radial and bilateral-symmetrical fundamental forms. Asymmetrical fundamental forms; (4) Anaxonia: irregular fundamental forms. Causes of form-construction. Fundamental forms of monera, protists, and histona. Fundamental form and mode of life. Beauty of natural forms. Æsthetics of organic forms. Art forms in nature.

The infinite variety of forms which we observe in the realm of organic life not only delight our senses with their beauty and diversity, but also excite our curiosity, in suggesting the problem of their origin and connection. While the æsthetic study of the forms of life provides inexhaustible material for the plastic arts, the scientific study of their relations, their structures, their origin and evolution, forms a special branch of biology, the science of forms or morphology. I expounded the principles of this science in my *General Morphology* thirty-eight years ago. They are so remote from the ordinary curriculum of education, and are so difficult to explain without the aid of numerous illustrations, that I cannot think of going fully into them here. In the present chapter I will only briefly describe those features of living things

which relate to the difficult question of their ideal fundamental forms, the laws of their symmetry, and their relation to crystal-formation. I have treated these intricate questions somewhat fully in the last (eleventh) part of *Art-forms in Nature*. The hundred plates contained in this work may serve as illustrations of morphological relations. In the following pages the respective plates are indicated by the letters A–f, with the number of each.

The unity of the organic structure, which expresses itself everywhere in the fundamental features of living things and in the chemical composition and constructive power of their plasm, is also seen in the laws of symmetry in their typical forms. The infinite variety of the species may, both in the animal and plant worlds, be reduced to a few principal groups or classes of fundamental forms, and these show no difference in the two kingdoms (*cf.* plate 6). The lily has the same regular typical form as the hexaradial coral or anemone (A–f. 9, 49), and the bilateral-radial form is the same in the violet and the sea-urchin (clypeaster, A–f. 30). The dorsiventral or bilateral-symmetrical form of most green leaves is repeated in the frame of most of the higher animals (the cœlomaria) ; the distinction of right and left determines in each the characteristic antithesis of back and belly.

The distinction between protists and histons is much more important than the familiar division of organisms into plants and animals, in respect of their fundamental forms and their configuration. For the protists, the unicellular organisms (without tissue) exhibit a much greater freedom and variety in the development of their fundamental forms than the histons, the multicellular tissue-forming organisms. In the protists (both protophyta and protozoa) the constructive force of the

elementary organism, the individual cell, determines the symmetry of the typical form and the special form of its supplementation; but in the histons (both metaphyta and metazoa) it is the plasticity of the tissue, made up of a number of socially combined cells, that determines this. On the ground of this tectological distinction we may divide the whole organic world into four kingdoms (or sub-kingdoms), as the morphological system in the seventh table shows.

In respect of the general science of fundamental forms (Promorphology), the most interesting and varied group of living things is the class of the radiolaria. All the various fundamental forms, that can be distinguished and defined mathematically, are found realised in the graceful flinty skeletons of these unicellular sea-dwelling protozoa. I have distinguished more than 4,000 forms of them, and illustrated by 140 plates, in my monograph on the Challenger-radiolaria [translated].

Only a very few organic forms seem to be quite irregular, without any trace of symmetry, or constantly changing their formless shape, as we find, for instance, in the amœbæ and the similar amœboid cells of the plasmodia. The great majority of organic bodies show a certain regularity both in their outer configuration and the construction of their various parts, which we may call "symmetry" in the wider sense of the word. The regularity of this symmetrical construction often expresses itself at first sight in the arrangement side by side of similar parts in a certain number and of a certain size, and in the possibility of distinguishing certain ideal axes and planes cutting each other at measurable angles. In this respect many organic forms are like inorganic crystals. The important branch of mineralogy that describes these crystalline forms, and gives them

mathematical formulæ, is called crystallography. There is a parallel branch of the science of biological forms, promorphology, which has been greatly neglected. These two branches of investigation have the common aim of detecting an ideal law of symmetry in the bodies they deal with, and expressing this in a definite mathematical formula.

The number of ideal fundamental forms, to which we may reduce the symmetries of the innumerable living organisms, is comparatively small. Formerly it was thought sufficient to distinguish two or three chief groups: (1) radial (or actinomorphic) types, (2) bilateral (or zygomorphic) types, and (3) irregular (or amorphic) types. But when we study the distinctive marks and differences of these types more closely, and take due account of the relations of the ideal axes and their poles, we are led to distinguish the nine groups or types which are found in the sixth table. In this promorphological system the determining factor is the disposition of the parts to the natural middle of the body. On this basis we make a first distinction into four classes or types: (1) the centrostigma have a *point* as the natural middle of the body; (2) the centraxonia a straight line (axis); (3) the centroplana a plane (median plane); and (4) the centraporia (acentra or anaxonia), the wholly irregular forms, have no distinguishable middle or symmetry.

1. Centrostigmatic Types.—The natural middle of the body is a mathematical point. Properly speaking, only one form is of this type, and that is the most regular of all, the sphere or ball. We may, however, distinguish two sub-classes, the smooth sphere and the flattened sphere. The smooth sphere (*holosphæra*) is a mathematically pure sphere, in which all points at the surface are equally distant from the centre, and all axes drawn through the centre are of equal length. We find this realised in its purity in the ovum of many animals (for instance, that of man and the mammals) and the

pollen cells of many plants; also cells that develop freely floating in a liquid, the simplest forms of the radiolaria (*actissa*), the spherical cœnobia of the volvocina and catallacta, and the corresponding pure embryonic form of the *blastula*. The smooth sphere is particularly important, because it is the only absolutely regular type, the sole form with a perfectly stable equilibrium, and at the same time the sole organic form which is susceptible of direct physical explanation. Inorganic fluids (drops of quicksilver, water, etc.) similarly assume the purely spherical form, as drops of oil do, for instance, when put in a watery fluid of the same specific weight (as a mixture of alcohol and water).

The flattened sphere, or facetted sphere (*platnosphæra*), is known as an endospherical polyhedron; that is to say, a many-surfaced body, all the corners of which fall in the surface of a sphere. The axes, or the diameters, which are drawn through the angles and the centre, are all unequal, and larger than all other axes (drawn through the facets). These facetted spheres are frequently found in the globular silicious skeletons of many of the radiolaria; the globular central capsule of many spheroidea is enclosed in a concentric gelatine envelope, on the round surface of which we find a network of fine silicious threads. The meshes of this net are sometimes regular (generally triangular or hexagonal), sometimes irregular; frequently star-like silicious needles rise from the knots of the network (A-f. 1, 51, 91). The pollen bodies in the flower-dust of many flowering plants also often assume the form of facetted spheres.

II. Centraxonia Types.—The natural middle of the body is a straight line, the principal axis. This large group of fundamental forms consists of two classes, according as each axis is the sole fixed ideal axis of the body, or other fixed transverse axes may also be distinguished, cutting the first at right angles. We call the former uniaxial (*monaxonia*), and the latter transverse-axial (*stauraxonia*). The horizontal section (vertically to the chief axis) is round in the uniaxials and polygonal in the transverse-axial.

In the monaxonia the form is determined by a single fixed axis, the principal axis; the two poles may be either equal (*isopola*) or unequal (*allopola*). To the *isopola* belong the familiar simple forms which are distinguished in geometry as spheroids, biconvex, ellipsoids, double cones, cylinders, etc. A horizontal section, passing through the middle of the vertical chief axis, divides the body into two corresponding halves. On the other hand, many of the parts are unequal in size and shape in the *allopola*. The upper pole or vertex differs from the basal pole or ground surface; as we find in the oval form, the planoconvex lens, the hemisphere, the cone, etc. Both sub-classes of the monaxonia, the allopola (conoidal) and the isopola (spheroidal), are found realised

frequently in organic forms, both in the tissue-cells of the histona and the independently living protists (A-f. 4, 84).

In the stauraxonia the vertical imaginary principal axis is cut by two or more horizontal cross-axes or radial-axes. This is the case in the forms which were formerly generally classed as regular or radial. Here also, as with the monaxonia, we may distinguish two sub-classes, isopola and allopola, according as the poles of the principal axis are equal or unequal.

Of the *stauraxonia isopola* we have, for instance, the double pyramids, one of the simplest forms of the octahedron. This form is exhibited very typically by most of the acantharia, the radiolaria in which twenty radial needles (consisting of silicated chalk) shoot out from the centre of the vertical chief axis. These twenty rays are (if we imagine the figure of the earth with its vertical axis) distributed in five horizontal zones, with four needles each, in this wise: two pairs cross at right angles in the equatorial zone, but on each side (in north and south hemispheres) the points of four needles fall in the tropical zone, and the points of four polar needles in the polar circles; twelve needles (the four equatorial and eight polar) lie in two meridian planes that are vertical to each other; and the eight tropical needles lie in two other meridian planes which cross the former at an angle of forty-five degrees. In most of the acantharia (the radial acanthometra and the mailed acanthophracta)—there are few exceptions—this remarkable structural law of twenty radial needles is faithfully maintained by heredity. Its origin is explained by adaptation to a regular attitude which the sea-dwelling unicellular body assumes in a certain stage of equilibrium (A-f. 21, 41). If the points of the real needles are connected by imaginary lines, we get a polyhedrical body, which may be reduced to the form of a regular double pyramid. This typical form of the equipolar stauraxonia is also found in other protists with a plastic skeleton, as in many diatomes and desmidiacea (A-f. 24). It is more rarely found embodied in the tissue-cells of the histona.

Unequipolar stauraxonia are the pyramids, a fundamental form that plays an important part in the configuration of organic bodies. They were formerly described as regular or fundamental forms. Such are the regular blooms of flowering plants, the regular echinoderms, medusæ, corals, etc. We may distinguish several groups of them according to the number of the horizontal transverse axes that cut the vertical main axis in the middle.

Two totally different divisions of the pyramidal types are the regular and the amphithecta pyramids. In the regular pyramids the transverse axes are equal, and the ground-surface (or base) is a regular polygon, as in the three-rayed blooms of the iris and crocus, the four-rayed medusæ

(A-f. 16, 28, 47, 48, etc.), the five-rayed "regular echinoderms," most of the star-fish, sea-urchins, etc. (A-f. 10, 40, 60), and the six-rayed "regular corals" (A-f. 9, 69).

The amphithecta (or two-edged) pyramids, a special group of pyramidal types, are characterised by having as their basis a rhombus instead of a regular polygon. We may, therefore, draw two imaginary transverse axes, vertical to each other, through the ground-surface, both equipolar, but of unequal length. One of the two may be called the sagittal axis (with dorsal and ventral pole), and the other the transverse axis (with right and left pole); but the distinction is arbitrary, as the two are equipolar. In this lies the chief difference from the centroplane and dorsiventral forms, in which only the lateral axis is equipolar, the sagittal axis being unequipolar. We find the bisected pyramid in a very perfect form in the class of the ctenophora (or comb-medusæ, A-f. 27), where it is quite general. The striking typical form of these pelagic cnidaria is sometimes called biradial, sometimes four-rayed and bilateral, and sometimes eight-rayed-symmetrical. Closer study shows it to be a rhombus-pyramid. The originally four-rayed type, which it inherited from craspedote medusæ, has become bilateral by the development of different organs to the right and left from those before and behind.

Similar rhombo-pyramidal forms to those of the ctenophora are also found in some of the medusæ and siphonophora, many of the corals and other cnidaria, and many flowers. The name "two-edged" which is given to this special type is taken from the ancient two-edged sword. Its chief axis is unequipolar, the handle being at the basic pole and the point at the verticle pole; but the two edges left and right are equal (poles of the lateral axis), and also the two broad surfaces (dorsal and ventral, joined by the sagittal axis).

III. Centroplane Types.—The natural middle of the body is a plane, the median or chief plane (*planum medianum* or *sagittale*); it divides the bilateral body into two symmetrical halves, the right and the left. With this is associated the characteristic antithesis of back (*dorsum*) and belly (*venter*); hence, in botany this type (found, for instance, in most green leaves) is called the dorsiventral, and in zoology the bilateral in the narrower sense. One characteristic of this important and widespread type is the relation of three different axes, vertical to each other; of these three straight axes (*enthyni*) two are unequipolar and the third equipolar. Hence, the centroplanes may also be called tri-axial (*triaxonia*). In most of the higher animals (as in our own frame) the longest of the three axes is the principal one (*axon principalis*); its fore pole is the oral or mouth pole, and its hinder pole is the aboral or caudal (tail) pole. The shortest of the three enthyni is, in our body, the sagittal (arrow) or dorsiventral axis; its upper pole is at the back and its lower

pole at the belly. The third axis—the transverse or lateral axis—is equipolar, one pole being called the right and the other the left. The various parts which make up the two halves of the body have relatively the same disposition in each half; but absolutely speaking (namely, in relation to the middle plane) they are oppositely arranged.

Further, the centroplane or bilateral forms are also characterised by three vertical axes which may be drawn through each of the normal axes. The first of these normal planes is the median plane; it is defined by the chief axis and the sagittal axis, and divides the body into two symmetrical halves, the right and left. The second normal plane is the frontal plane; this passes through the chief axis and the transverse axis (which is parallel to the frontal surface in our body), and divides the dorsal half from the ventral half. The third normal plane is the cingular (waist) plane; this is defined by the sagittal and transverse axes. It divides the head half (or the vertical part) from the tail half (or the basal part).

The name "bilateral symmetry," which is especially applied to the centroplane and dorsiventral types, is ambiguous, as I pointed out in 1866 in an exhaustive analysis and criticism of these fundamental forms in the fourth book of the *General Morphology*. It is used in five different senses. For our present general purpose it suffices to distinguish two orders of centroplane types, the bilateral-radial and the bilateral-symmetrical; in the former the radial (pyramidal) form is combined with the bilateral, but not in the latter.

The bilateral-radial type comprises those forms in which the radial structure is combined in a very characteristic fashion with the bilateral. We have striking examples in the three-rayed flowers of the orchids (A-f. 74), the five-rayed blooms of the labiate and papilionaceous flowers, etc., in the plant world; and in the five-rayed "irregular" echinoderms, the bilateral sea-urchins (spatangida, clypeastrida, A-f. 30) in the animal world. In these cases the bilateral symmetry is recognisable at the first glance, as is also the radial structure, or the composition from three to five or more ray-like parts (*paramera*), which are arranged bilaterally round a common central plane.

The bilateral-symmetrical type is general among the higher animals which move about freely. The body consists of two antithetic parts (*antimera*), and has no trace of radial structure. In the free moving, creeping, or swimming animals (vertebrates, articulates, molluscs, annelids, etc.) the ventral side is underneath, against the ground, and the dorsal side upward. This form is clearly the most useful and practical of all conceivable types for the movement of the body in a definite direction and position. The burden is equally distributed between the two sides (right and left); the head (with the sense organs, the brain, and the mouth) faces frontwards and the tail behind. For thousands of years

all artificial vehicles (carts on land and ships in water) have been built on this type. Selection has recognised it to be the best and preserved it, while it has discarded the rest. There are, however, other causes that have produced the predominance of this type in green leaves—the relation to the supporting stalk, to the sun light that falls from above, etc.

Special notice must be taken of those bilateral forms which were originally symmetrical (by heredity), but have subsequently become asymmetrical (or of unequal halves), by adaptation to special conditions of life. The most familiar example among the vertebrates are the flat-fishes (*pleuronectides*), soles, flounders, turbots, etc. These high and narrow and flattened boney-fishes have a perfect bilateral symmetry when young, like ordinary fishes. Afterwards they form the habit of laying on one side (right or left) at the bottom of the sea; and in consequence the upper side, exposed to the light, is dark coloured, and often marked with a design (sometimes very like the stoney floor of the ocean—a protective colouring), while the side the flat-fish lies on remains without colour. But, what is more curious, the eye from the under side travels to the upper side, and the two eyes lie together on one side (the right or left); while the bones of the skull and the softer parts of each side of the head grow quite crooked. Naturally, this ontogenetic process, in which a striking lack of symmetry succeeds to the early complete symmetry of each individual, can only be explained by our biogenetic law; it is a rapid and brief recapitulation (determined by heredity) of the long and slow phyletic process which the flat-fish has undergone for thousands of years in its ancestral history to bring about its gradual modification. At the same time, this interesting metamorphosis of the *pleuronectides* gives us an excellent instance of the inheritance of acquired characteristics, as a consequence

of constant œcological habit. It is quite impossible to explain it on Weismann's theory of the germ-plasm.

We have another striking example among the invertebrates in the snails (*gasteropoda*). The great majority of these molluscs are characterised by the spiral shape of their shells. This variously shaped, and often prettily coloured and marked, snail's house is in essence a spirally coiled tube, closed at the upper end and open at the lower (or mouth) : the mollusc can at any moment withdraw into its tube. The comparative anatomy and ontogeny of the snails teach us that this spiral shell came originally from a simple discoid or cylindrical dorsal covering of the once bilateral-symmetrical mollusc, by the two sides of the body having an unequal growth. The cause of it was a purely mechanical factor—the sinking of the growing visceral sac, covered with the shell, to one side ; one part of the viscera contained in it (the heart, kidneys, liver, etc.) grew more strongly on one side than the other in consequence of this ; and this was accompanied by considerable displacement and modification of the neighbouring parts, especially the gills. In most snails one of the gills and kidneys and the ventricle of the heart corresponding to these have disappeared altogether, only those of the opposite side remaining ; and the latter have moved from the right side to the left, or *vice versa*. The conspicuous lack of symmetry between the two halves of the body which resulted from this finds expression in the spiral form of the snail's shell. This remarkable ontogenetic metamorphosis also can be fully explained by a corresponding phylogenetic process, and affords a very fine instance of the inheritance of acquired characters.

There are also many examples of this asymmetry of

bilateral forms in the plant world, such as the green foliage-leaves of the familiar begonia and the blooms of *canna*.

IV. The Centraporia.—Few organic forms are completely irregular and without axes, as usually the attraction to the earth (*geotaxis*) or to the nearest object determines the special direction of growth, and so the formation of an axis in some direction or other. Nevertheless, we may instance as quite irregular the soft and ever-changing plasma-bodies of many rhizopods, the amœbinæ, mycetozoa, etc. Most of the sponges also—which we regard as stocks of gastræads—are completely irregular in structure; the most familiar example is the common bath-sponge.

An impartial and thorough study of organic forms has convinced me that their actual, infinitely varied configurations may all be reduced to the few typical forms I have described. Comparative anatomy and ontogeny further teach us that the countless modifying processes which have led to the appearance of the various species have acted by adaptation to different environments, habits, and customs, and give us, in conjunction with heredity, a physiological explanation of this morphological transformation. But the question arises as to the origin of these few geometrically definable types, and the cause of their divergence.

In this important and difficult question we find a great variety of opinions and a strong leaning to dualistic and mystic theories. Educated laymen, who have only a partial and imperfect acquaintance with the biological facts, think that they are justified here in appealing to a supernatural creation of forms. They contend that only a wise creator, following a rational and conscious design, could produce such structures. Even distinguished and

informed scientists lean in this matter towards mystic and transcendental ideas; they believe that the ordinary natural forces do not suffice to explain these phenomena, and that at least for the first construction of these fundamental types we must postulate a deliberate creative thought, a design, or some such teleological cause, and therefore consciously acting final causes. So say Nägeli and Alexander Braun.

In direct opposition to this, I have ever maintained the view that the action of familiar physical forces—mechanical efficient causes—fully suffices to explain the origin and transformation of these fundamental types, as well as for all other biological and inorganic processes. In order to understand this monistic position thoroughly, and to meet the errors of dualism, we must bear in mind always the radical processes of growth which control all organic and inorganic configuration, and also the long chain of advancing stages of development, which lead us from the simplest protists, the monera, to the most advanced organisms.

The unicellular organisms exhibit the greatest variety from the promorphological point of view. In the single class of the radiolaria we find all imaginable geometrical types represented. This is seen in a glance at the 140 plates on which I have depicted thousands of these graceful little protozoa in my monograph (*Challenger Report*, vol. xviii.). On the other hand, the monera, at the lowest stage of organic life, the structureless organisms without organs that live on the very frontier of the inorganic world, are very simple. Especially interesting in this connection are the chromacea, which have hitherto been so undeservedly and so incomprehensibly neglected. Among the well-known and widely distributed chroococcacea, the chroococcus, cœlosphærium, and aphanocapsa

are quite the most primitive of all organisms known to us—and at the same time the organisms that enable us best to understand the origin of life by spontaneous generation (archigony). The whole organism is merely a tiny, bluish-green globule of plasm, without any structure, or only surrounded by a thin membrane; its fundamental form is the simplest of all, the centraxial smooth sphere. Next to these are the oscillaria and nostochina, social chromacea, which have the appearance of thin, bluish-green threads. They consist of simple primitive (unnucleated) cells joined to each other; they seem often to be flattened into a discoid shape as a result of close conjunction. Many protists are found in two conditions, one mobile with very varied and changeable forms, and one stationary with a globular shape. But when the separate living cell begins to form a firm skeleton or protective cover for itself, it may assume the most varied and often most complicated forms. In this respect the class of the radiolaria among the protozoa, and the class of the diatomes among the protophyta (both of which have flinty shells), surpass all the other groups of the diversified realm of the protists. In my *Art-forms in Nature* I have given a selection of their most beautiful forms (diatomes, A–f. 4, 84; radiolaria, A–f. 1, 11, 21, 22, 31, 41, 51, 61, 71, 95). The most remarkable and most important fact about them is that the artistic builders of these wonderful and often very ingenious and intricate flinty structures are merely the plastidules or micella, the molecular and microscopically invisible constituents of the soft viscous plasm (sarcode).

The configuration of the histona differs essentially from that of the protists, since in the case of the latter the simple unicellular body produces for itself alone the whole form and vital action of the organism, while in

the histona this is done by the cell state, or the social combination of a number of different cells, which make up the tissue body. Hence the ideal type which we can always define in the actual histonal form has quite a different significance from that in the unicellular protists. In the latter we find the utmost diversity in the configuration of the independent living cells and the protective cover it forms; among the histona the number of fundamental forms is limited. It is true that the cells themselves which make up the tissues may exhibit a great variety in form and structure; but the number of the different tissues which they make up is small, and so is the number of ideal types exhibited by the organism they combine to form—the sprout *(culmus)* in the plant kingdom and the person in the animal kingdom. The same may be said of the stock *(cormus)* in both kingdoms—that is to say, of the higher individual unity which is constituted by the union of several sprouts or persons.

The two classes of fundamental forms which are especially found in the plant sprouts or the animal persons are the radial and bilateral. The one is determined by the stationary life, the other by free movement in a certain attitude and direction (swimming in water or creeping on the ground). Hence we find the radial form (as pyramidal) predominant in the blooms and fruits of the metaphyta, and the persons of the polyps, corals, and regular echinoderms. On the other hand, the bilateral or dorsiventral form preponderates in most free-moving animals; though it is also found in many flowers (papilionaceous and labial flowers, orchids, and others that are fertilised by insects). Here we have to seek the cause of the bilateralism in different features, in the relations with the insects, in the mode of their

fastening to and distribution on the stalk (for the green foliage leaves), and so on.

The complex individuals of the first order, the stocks *(cormi)*, are more dependent in their growth on the spatial conditions of their environment than the sprouts or persons; hence their typical form is generally more or less irregular, and rarely bilateral.

The interest which we take in natural and artistic forms, and which has for thousands of years prompted men to reproduce the former in the latter, depends for the most part, if not altogether, on their beauty—that is to say, on the feeling of pleasure we experience in looking at them. The causes of this pleasure and joy in the beautiful and the naturalness of its development are explained in æsthetics. When we combine this science with the results of modern cerebral physiology, we may distinguish two classes of beauty—direct and indirect. In direct or sensible beauty the internal sense-organs, or the æsthetic neurona or sense cells of the brain, are immediately affected with pleasure. But in indirect or associational beauty these impressions are combined with an excitement of the phronetic neurona—the rational brain—cells which effect presentation and thought.

Direct or sensible beauty (the subject of sensual æsthetics) is the direct perception of agreeable stimuli by the sense-organs. We may distinguish the following stages of its perfection: 1. Simple beauty (the subject of primordial æsthetics); the pleasure is evoked by the direct sense-impression of a simple form or colour. Thus, for instance, a wooden sphere makes an agreeable impression as compared with a shapeless piece of wood, a crystal as compared with a stone, a sky-blue or golden-yellow spot as compared with a greenish-blue or

dull-yellow one (in music a simple pure bell-tone as compared with a shrill whistle). 2. Rythmic beauty (the subject of linear æsthetics); the æsthetic sensation is caused by the serial repetition of some simple form—for instance, a pearl necklace, a chain-like community of monera (nostoc) or of cells (diatomes, a.–f. 84, figs. 7 and 9): in music a tasteful series of simple notes. 3. Actinal beauty (the subject of radial æsthetics); the pleasure is excited by the orderly arrangement of three or more homogeneous simple forms about a common centre, from which they radiate; for instance, a regular cross or a radiating star, the three counter-pieces in the iris-bloom, the four paramera in the body of the medusa, the five radial-pieces in the star fish. The familiar experience of the kaleidoscope shows how amply the simple radial constellation of three or more simple figures may delight our æsthetic sense (in music we have the simple harmony of several simultaneous notes). 4. Symmetrical beauty (the subject of bilateral æsthetics); the pleasure is caused by the relation of a simple object to its like, the mutual completion of two similar halves (the right and left parts). When we fold a piece of paper over an ink-stain in such a way that it is equally impressed on both halves of the fold, we get a symmetrical figure which makes an agreeable impression on our natural sense of space or equilibrium.

The æsthetic impressions in indirect associational beauty (the subject of associative or symbolical æsthetics) are not only much more varied and complex than those we have described, but they also play a much more important part in the life of man and the higher animals. The anatomic condition for this higher physiological function is the elaborate construction of the brain in the higher animals and man, and particularly the development of

the special association-centres (thought-centres, reason-sphere) and their differentiation from the internal sense-centres. In this millions of different neurona or psychic cells co-operate, the sensual æstheta acting in conjunction with the rational phroneta, and thus, by complex associations of ideas, much higher and more valuable functions arise. We may indicate four chief groups of this associational or indirect beauty. 5. Biological beauty (the subject of botanical and zoological æsthetics): the various forms of organisms and their organs (for instance, a flower, a butterfly) excite our æsthetic interest by association with their physiological significance, their movements, their bionomic relations, their practical use, and so on. 6. Anthropistic beauty (the subject of anthropomorphic æsthetics): man, as "the measure of all things," regards his own organism as the chief object of beauty, either morphologically considered (beauty of the whole body and its various organs—the eyes, mouth, hair, flesh-tint, etc.), or physiologically (beauty of movements or positions), or psychologically (the expression of the emotions in the physiognomy). As man transfers to the objective world this personal gratification he experiences from self-consideration, and anthropomorphically regards other beings in the light of them, this anthropistic æsthetic obtains a far-reaching significance. 7. Sexual beauty (the subject of erotic æsthetics): the pleasure is caused by the mutual attraction of the sexes. The supreme importance of love in the life of man and most other organisms, the powerful influence of the passions, the sexual selection that is associated with reproduction, have evoked an infinite number of æsthetic creations in every branch of art relating to the antithesis of man and woman. The special pleasure which is caused by the bodily and mental affinities of the

sexes can be traced phylogenetically to the cell-love of the two sexual cells, or the attraction of the sperm-cell to ovum. 8. Landscape beauty (the subject of regional æsthetics); the pleasure which is caused by the sight of a fine landscape, and that finds satisfaction in modern landscape-painting, is more comprehensive than that of any other æsthetic sensations. In point of space the object is larger and richer than any of the individual objects in nature which are beautiful and interesting in themselves. The varying forms of the clouds and the water, the outline of the blue mountains in the back-ground, the woods and meadows in the middle-distance, and the living figures in the fore-ground, excite in the mind of the spectator a number of different impressions which are woven together into a harmonious whole by a most elaborate association of ideas. The physiological functions of the nerve-cells in the cortex which effect these æsthetic pleasures, and the interaction of the sensual æstheta with the rational phroneta, are among the most perfect achievements of organic life. This "regional æsthetics," which has to establish scientifically the laws of landscape beauty, is much younger than the other branches of the science of the beautiful. It is very remarkable that absolute irregularity, the absence of symmetry and mathematical forms, is the first condition for the beauty of a landscape (as contrasted with architecture, and the beauty of separate objects in nature). Symmetrical arrangement of things (such as a double row of poplars or houses) or radial figures (a flower-bed or artificial wood) do not please the finer taste for landscape; they seem tedious.

A comparative survey of these eight kinds of beauty in natural forms discovers a connected development, rising from the simple to the complex, from the lower

to the higher. This scale corresponds to the evolution of the sense of beauty in man, ontogenetically from the child to the adult, phylogenetically from the savage to the civilised man and the art critic. The stem-history of man and his organs, which explains to us in anthropogeny the gradual rise from lower to higher forms by the interaction of heredity and adaptation, also finds an application in the history of æsthetics and ornamentation. It teaches us how feeling, taste, emotion, and art have been gradually evolved. On the other hand, we have corresponding to this evolutionary series the scale of the typical forms which lie at the root of the real forms of bodies both in nature and art.

# Seventh Table.

## THE MORPHOLOGICAL SYSTEM OF ORGANISMS.

Division of living things (plants and animals) into two kingdoms (protista and histona) on the ground of their cell-structure and body-structure.

**First organic kingdom: Unicellular, protista.**

Organisms which as a rule remain unicellular throughout life (*monobia*), less frequently they form loose cell communities (*cenobia*) by repeated cleavage, but never real tissues.

Sub-kingdom of the protista.

**Second organic kingdom: Multicellular, histona.**

Organisms which are only unicellular at the beginning of their existence, are later multicellular, and always form real tissues (*histobia*) by the firm conjunction of social cells.

Sub-kingdom of the histona.

### A. Primitive Plants (protophyta).

A. Character: Plasmodomous.

Unicellulars with vegetal metabolism: Carbon-assimilation.

Chief Groups:

I. Phytomonera.

Protophyta without nucleus (monera)
Chromacea.

II. Algariæ.

Unicellular algæ with nucleus, without ciliary motion: Paulotomea, diatomea.

III. Algettæ.

Unicellular algæ with nucleus, and with ciliary motion: Mastigota, melethallia, siphonea.

### B. Primitive Animals (protozoa).

B. Character: Plasmophagous.

Unicellulars with animal metabolism: Albumin-assimilation.

Chief Groups:

I. Zoomonera.

Protozoa without nucleus (monera)
Bacteria.

II. Sporozoa.

Nucleated protozoa without mobile processes: Gregarinæ, chytridinæ.

III. Rhizopoda.

Nucleated protozoa with pseudopodia: Labosa, radiolaria.

IV. Infusoria.

Nucleated protozoa with cilia or lashes: Flagellata, ciliata.

### C. Tissue Plants. (metaphyta).

C. Character: Plasmodomous.

Multicellulars with vegetal metabolism: Carbon-assimilation.

Chief Groups:

I. Thallophyta.

Thallus-plants. Metapyta with thallus: Algæ, mycetæ (fungi).

II. Mesophyta.

Median plants, with prothallium: Mosses, ferns (muscinæ, filicinæ).

III. Anthophyta (phanerogams).

Flowering plants, with blooms and seeds (spermophyta): Gymnosperms, angiosperms.

### D. Tissue Animals (metazoa).

D. Character: Phasmophagous.

Multicellulars with animal metabolism: Albumin-assimilation.

Chief Groups:

I. Cœlenteria (cœlenterata).

Metazoa without body cavity and anus: Gastræada. Sponges, cnidaria, platodes.

II. Cœlomaria (bilaterals).

Metazoa with body cavity and anus (generally also blood vessels): Vermalia, mollusca, echinoderma, articulata, tunicata, vertebrata.

## Chapter IX.

# MONERA

**The simplest forms of life. Cell theory and cell dogma. Precellular organisms: monera, cytodes, and cells. Actual monera. Chromacea (cyanophyceæ). Chromatophora. Cenobia of chromacea: vital phenomena. Bacteria. Relations of the bacteria to the chromacea, the fungi, and the protozoa. Rhizomonera (protamœba, protogenes, protomyxa, bathybius). Problematic monera. Phytomonera (plasmodoma) and zoomonera (plasmophaga). Transition between the two classes.**

In the study and explanation of all complex phenomena the first thing to do is to understand the simple parts, the manner of their combination, and the development of the compound from the simple. This principle applies generally to inorganic objects, such as minerals, artificially constructed machines, etc. It is also of general application in biological work. The efforts of comparative anatomy are directed to the comprehension of the intricate structure of the higher organisms from the rising scale of organisation and life in the lower, and the origin of the former by historical development from the latter. The modern science of the cell (cytology), which has in a short time attained a considerable rank, pursues a method in opposition to this principle. The intricate composition of the unicellular organism, in many of the higher protists (such as the ciliata and infusoria) and many of the higher tissue-cells (such as the neurona) has led to the erroneous ascription of a highly complex organisation to the cell in general. One

would be justified in saying that of late the cell theory has established itself in the dangerous and misleading position of a cell-dogma.

The modern treatment of the science, as we find it in numbers of recent works, even in some of the most distinguished manuals, and which we must resent on account of its dogmatism, culminates in something like the following theses:—

1. The nucleated cell is the general elementary organism; all living things are either unicellular, or made up of a number of cells and tissues.

2. This elementary organism consists of at least two different organs (or, more correctly, organella), the internal nucleus and the outer cell-body (or cytoplasm).

3. The matter in each of these cell-organs—the caryoplasm of the nucleus and the cytoplasm of the body—is never homogeneous (or consisting of a chemical substratum), but always "organised," or made up of several chemically and anatomically different elementary constituents.

4. The plasm (or protoplasm) is, therefore, a morphological, not a chemical, unity.

5. Every cell comes (and has come) only from a mother-cell, and every nucleus from a mother-nucleus *(omnis cellula e cellula—omnis nucleus e nucleo)*.

These five theses of the modern cell-dogma are by no means sound; they are incompatible with the theory of evolution. I have, therefore, consistently resisted them for thirty-eight years, and consider them to be so dangerous that I will briefly give my reasons. First, let us clearly understand the modern definition of the cell. It is now generally defined (in accordance with the second thesis) as being composed of two essentially different parts, the nucleus and the cell-body, and it is

added that these organella differ constantly both in respect of chemistry, morphology, and physiology. If that is really so, the cell cannot possibly be the primitive organism; if it were, we should have a miracle at the beginning of organic life on the earth. The theory of natural evolution clearly and distinctly demands that the cell (in this sense) is a secondary development from a simpler, primary, elementary organism, a homogeneous cytode. There are still living to-day very simple protists which do not tally with this definition, and which I designated *monera* in 1866. As they must necessarily have preceded the real cells, they may also be called "precellular organisms."

The earliest organisms to live on the earth, with which the wonderful drama of life began, can, in the present condition of biological science, only be conceived as homogeneous particles of plasm—biogens or groups of biogens, in which there was not yet the division of nucleus and cell-body which characterises the real cell. I gave the name "cytodes" to these unnucleated cells in 1866, and joined them with the real nucleated cells under the general head of "plastids." I also endeavoured to prove that such cytodes still exist in the form of independent monera, and in 1870 I described in my *Monograph on the Monera* a number of protists which do not tally with the above definition.

Fifty years ago I made the first careful observations of living monera (*protamœba* and *protogenes*), and described them in my *General Morphology* (vol. i., p. 133–5, vol. ii., p. xxii.) as structureless organisms without organs and the real beginnings of organic life. Soon afterwards, during a stay in the Canary Islands, I succeeded in following the continuous life-history of a related organism of the rhizopod type, which behaved like a very simple

mycetozoon, but differed in having no nucleus; I have reproduced the picture of it in the first plate of my *History of Creation.* The description of this orange-red globule of plasm (*protomyxa aurantiaca*) appeared first in my *Monograph on the Monera.* Most of the organisms which I comprised under this name exhibited the same movements as true rhizopods (or sarcodina). It was afterwards proved of some of them that there was a nucleus hidden within the homogeneous particle of plasm, and that, therefore, they must be regarded as real cells. But this discovery was wrongly extended to the whole of the monera, and the existence of unnucleated organisms was denied altogether. Nevertheless, there are living to-day several kinds of these organisms without organs, some of them being very widely distributed. The chief examples are the chromacea and the bacteria, the former with vegetal and the latter with animal metabolism (or the former plasmodomous = plasma-forming, and the latter plasmophagous = plasma-feeding). On the ground of this important chemical difference, I distinguished two principal groups of the monera in my *Systematic Phylogeny* twenty years ago—the phytomonera and the zoomonera, the former being unnucleated protophyta and the latter unnucleated protozoa.

Among living organisms the chromacea are certainly the most primitive and the nearest to the oldest inhabitants of the earth. Their simplest forms, the chroococcacea, are nothing but small structureless particles of plasm, growing by plasmodomism (formation of plasm) and multiplying by simple cleavage as soon as their growth passes a certain limit of individual size. Many of them are surrounded by a thin membrane or somewhat thicker gelatinous covering, and this circumstance had prevented me for some time from counting the chromacea as

monera. However, I became convinced afterwards that the formation of a protective cover of this kind around the homogeneous particle of plasm may indeed be regarded from the physiological standpoint as a "purposive" structure, but at the same time may be looked upon, from the purely physical standpoint, as a result of superficial strain. On the other hand, the physiological character of these plasmodomous monera is especially important, as it gives us the simple key to the solution of the great question of spontaneous generation (or archigony, *cf.* chap. xv.).

The chromacea are to-day found in every part of the earth, living sometimes in fresh water and sometimes in the sea. Many species form blue-green, violet, or reddish deposits on rocks, stones, wood, and other objects. In these thin gelatinous plates millions of small homogeneous cytodes are packed close together. Their tint is due to a peculiar colouring matter (phycocyan), which is chemically connected with the substance of the plasma-particle. The shade of this colour differs a good deal in the various species of chromacea (of which more than 800 have been distinguished); in the native species it is generally blue-green or sage-green, sometimes blue, cyanine blue, or violet. Hence the common name cyanophyceæ (*i.e.*, blue algæ). It is incorrect, for two reasons; firstly, because only a part of these protophyta are blue, and, secondly, because they (as simple, primitive plants without tissue) must be distinguished from the real algæ (phyceæ), which are multicellular, tissue-forming plants. Other chromacea are red, orange, or yellow in colour, as the interesting *trichodesmium erythræum*, for instance, the flaky masses of which, gathering in enormous quantities, cause at certain times the yellow or red colouring of the sea water

in the tropics; it is these that are responsible for the name "Red Sea" on the Arabian and "Yellow Sea" on the Chinese coast. When I passed the equator in the Sunda Straits on March 10th, 1901, the boat sailed through colossal accumulations, several miles in width, of this trichodesmium. The yellow or reddish surface of the water looked as if it were strewn with sawdust. In the same way, the surface of the Arctic Ocean is often coloured brown or reddish-brown by masses of the brown *procytella primordialis* (formerly described as *protococcus marinus*).

It is clearly quite illogical to regard the chromacea as a class or family of the algæ, as is still done in most manuals of botany. The real algæ—excluding the unicellular diatomes and paulotomes, which belong to the protophyta—are multicellular plants that form a *thallus* or bed of a certain form and characteristic tissue. The chromacea, which have not advanced as far as the real nucleated cell, are unnucleated cytodes of a lower and earlier stage of plant life. If one would compare the chromacea with algæ or other plants at all, the comparison cannot be with their constituent cells, but merely with the chromatophora or chromatella, which are found in all green plant-cells, and form *part* of their contents. To be more precise, these green granules of chlorophyll must be regarded as organella of the plant cell, or separated plasma-formations which arise beside the nucleus in the cytoplasm. In the embryonic cells of the germs of plants and in their vegetation points the chromatophora are as yet colourless, and are developed, as solid, very refractive, globular, or roundish granules, from the firm layer of plasm which immediately surrounds the nucleus. Afterwards they are converted, by a chemical process, into the green

chlorophyll granules or chloroplasts, which have the most important function in the plasmodomism or carbon-assimilation of the plant.

The fact that the green chlorophyll granules grow independently within the living plant-cell and multiply by segmentation is very important and interesting. The globular chloroplasts are constricted in the middle, and split into two equal daughter-globules. These daughter-plastids grow, and multiply in turn in the same way. Hence they behave within the plant-cell just like the free-living chromacea in the water. On the strength of this significant comparison, one of our ablest and most open-minded scientists, Fritz Müller-Desterro, of Brazil, pointed out in 1893 that we may see in every green vegetal cell a symbiosis between plasmodomous green and plasmophagous not-green companions (*cf.* my *Anthropogeny*, figs. 277 and 278, and in the text).

Many species of the simplest chromacea live as monobia (individually). When the tiny plasma globules have split into two equal halves by simple segmentation, they separate, and live their lives apart. This is the case with the common, ubiquitous chroococcus. However, most species live in common, the plasma granules forming more or less thick cœnobia, or communities or colonies of cells. In the simplest case *(aphanocapsa)* the social cytodes secrete a structureless gelatinous mass, in which numbers of blue-green plasma globules are irregularly distributed. In the *glœocapsa*, which forms a thin blue-green gelatinous deposit on damp walls and rocks, the constituent cytodes cover themselves immediately after cleavage with a fresh gelatinous envelope, and these run together into large masses. But the majority of the chromacea form firm, thread-like cell communities or chains of plastids (catenal cœnobia). As the transverse

cleavage of the rapidly-multiplying cytodes always follows the same direction, and the new daughter-cytodes remain joined at the cleavage surfaces, and are flattened into discoid shape, we get string-like formations or articulated threads of considerable length, as in the oscillaria and nostochina. When a number of these threads are joined together in gelatinous masses, we often get large, irregular jelly-like bodies, as in the common "shooting-star jellies" *(nostoc communis)*. They attain the size of a plum.

In view of the extreme importance which I attach to the chromacea as the earliest and simplest of all organisms, it is necessary to put clearly the following facts with regard to their anatomic structure and physiological activity :—

1. The organism of the simplest chromacea is *not* composed of different organella or organs ; and it shows no trace of purposive construction or definite architecture.

2. The homogeneous tinted plasma granule which makes up the entire organism in the simplest case *(chroococcus)* exhibits no plasma structure (honeycomb, threads, etc.) whatever.

3. The original globular form of the plasma particle is the simplest of all fundamental types, and is also that assumed by the inorganic body (such as a drop of rain) in a condition of stable equilibrium.

4. The formation of a thin membrane at the surface of the structureless plasma granule may be explained as a purely physical process—that of surface strain.

5. The gelatinous envelope which is secreted by many of the chromacea is also formed by a simple physical (or chemical) process.

6. The sole essential vital function that is common to

all the chromacea is self-maintenance, and growth by means of their vegetal metabolism, or plasmodomism (= carbon assimilation); this purely chemical process is on a level with the catalysis of inorganic compounds (chap. x.).

7. The growth of the cytodes, in virtue of their continuous plasmodomism, is on a level with the physical process of crystal growth.

8. The reproduction of the chromacea by simple cleavage is merely the continuation of this simple growth process, when it passes the limit of individual size.

9. All the other vital phenomena which are to be seen in some of the chromacea can also be explained by physical or chemical causes on mechanical principles. Not a single fact compels us to assume a "vital force."

Especially noteworthy in regard to the physiological character of these lowest organisms are their bionomic peculiarities, especially the indifference to external influences, higher and lower temperatures, etc. Many of the chromacea live in hot springs, with a temperature of 50–80° C., in which no other organism is found. Other species may remain for a long time frozen in ice, and resume their vital activity as soon as it thaws. Many chromacea may be completely dried up, and then resume their life if put in water after several years.

Next in order to the chromacea we have the bacteria, the remarkable little organisms which have been well known in the last few decades as the causes of fatal diseases, and the agents of fermentation, putrefaction, etc. The special science which is concerned with them—modern bacteriology—has attained so important a position in a short period—especially as regards practical and theoretical medicine—that it is now represented by separate chairs at most of the universities. We may

admire the penetration and the perseverance with which scientists have succeeded, with the aid of the best modern microscopes and methods of preparation and colouring, in making so close a study of the organism of the bacteria, determining their physiological properties, and explaining their great importance for organic life by careful experiments and methods of culture. The bionomic or œconomic position of the bacteria in Nature's household has thus secured for these tiny organisms the greatest scientific and practical interest.

However, we find that certain general views have been maintained by specialists in bacteriology up to our own time, which are in curious contrast with these brilliant results. The biologist who studies the systematic relations of the bacteria from the modern point of view of the theory of descent is bewildered at the extraordinary views as to the place of the bacteria in the plant-world (as segmentation-fungi), their relations to other classes of plants, and the formation of their species. When we carefully consider the morphological properties that are common to all true bacteria and compare them with other organisms, we are forced to the conclusion that I urged years ago in various writings: the bacteria are not real (nucleated) cells, but unnucleated cytodes of the rank of the monera; they are not real (tissue-forming) fungi, but simple protists; their nearest relatives are the chromacea.

The individual organisms of the simplest kind, which bacteriologists call "bacteria-cells," are not real nucleated cells. That is the clear negative result of a number of most careful investigations which have been made up to date with the object of finding a nucleus in the plasma-body of the bacteria. Among recent exact investigations we must especially note those of the botanist Reinke, of

Kiel, who sought in vain to detect a nucleus in one of the largest and most easily studied genera of the bacteria, the *beggiatoa*, using every modern technical aid. His conviction that this important cell-structure is really lacking is the more valuable, as it is very prejudicial to his own theory of "dominants." Other scientists (especially Schaudinn) have recently claimed, as equivalent to a nucleus in some of the larger bacteria, a number of very small granules, which are irregularly distributed in the plasm, and are strongly tinted under certain colouring processes. But even if the chemical identity of these substances which take the same colour were proved—which is certainly not the case—and even if the appearance of scattered nuclein-granules in the plasm could be regarded as a preliminary to, or a beginning of, the differentiation of an individual, morphologically distinct nucleus, we should not yet have shown its independence as an organellum of the cell.

Nor is this any more proved from the circumstance that in some bacteria (not all) we find a severance of the plasm into an inner and outer layer, or a frothy structure with vacuole-formation, or a special sharply-outlined membrane on the plastid. Many bacteria (but not all) have such a membrane, like the nearly related chromacea, and also the secretion of a gelatine envelope. Both classes have also in common an exclusively monogenetic reproduction. The bacteria multiply, like the chromacea, by simple segmentation; as soon as the structureless plasma-granule has reached a certain size by simple growth, it is constricted and splits into two halves. In the long-bodied bacteria (the rod-shaped bacilli) the constriction always goes through the middle of the long axis, and is, therefore, simple transverse cleavage. Many bacteria have also been said to multiply by the formation

of spores. But these so-called "spores" are really permanent quiescent forms (without any multiplication of individuals); the central part of the plastid (endoplasm) condenses, separates from the peripheral part (exoplasm), and undergoes a chemical change which makes it very indifferent to external influences (such as a high temperature).

The great majority of the bacteria differ so little morphologically from the chromacea that we can only distinguish these two classes of monera by the difference in their metabolism. The chromacea, as protophyta, are plasmodomous. They form new plasm by synthesis and reduction from simple inorganic compounds—water, carbonic acid, ammonia, nitric acid, etc. But the bacteria, as protozoa, are plasmophagous. They cannot, as a rule, form new plasm, but have to take it from other organisms (as parasites, saprophytes, etc.); they decompose it by analysis and oxydation. Hence the colourless bacteria are without the important green, blue, or red colouring matter (phycocyan) which tints the plastids of the chromacea, and is the real instrument of the carbon-assimilation. However, there are exceptions in this respect: *bacillus virens* is tinted green with chlorophyll, *micrococcus prodigiosus* is blood-red, other bacteria purple, and so on. Certain earth-dwelling bacteria *(nitrobacteria)* have the vegetal property of plasmodomism; they convert ammonia by oxydation into nitrous acid, and this into nitric acid, using as their source of carbon the carbonic acid gas in the atmosphere. They are thus quite independent of organic substances, and feed, like the chromacea, on simple inorganic compounds.

Hence the affinity between the plasmodomous chromacea and plasmophagous bacteria is so close that it is

impossible to give a single safe criterion that will effectually separate the two classes. Many botanists accordingly combine both groups in a single class with the name of *schizophyta*, and within this distinguish as "orders" the blue-green chromacea as *schizophyceæ* (cleavage-algæ) and the colourless bacteria as *schizomycetes* (cleavage-fungi). However, we must not take this division too rigidly; and the absolute lack of a nucleus and tissue-formation separates the chromacea just as widely from the multicellular tissue-forming algæ as the bacteria from the fungi. The simple multiplication by the halving of the cell, which is expressed in the name "cleavage-plants" *(schizophyta)*, is also found in many other protists.

The number of forms that can be distinguished as species in the technical sense is very great in the case of the bacteria, in spite of the extreme simplicity of their outward appearance; many biologists speak of several hundred, and even of more than a thousand, species. But when we look solely to the outer form of the living plasma-granule, we can only distinguish three fundamental types: (1) Micrococci, or spherobacteria (briefly, cocci), globular or ellipsoid; (2) bacilli, or rhabdo-bacteria (also called eubacteria, or bacteria in the narrower sense), rod-shaped, cylindrical, and often twisted like worms (comma-bacilli); (3) spirilla, or spirobacteria, screw-shaped rods (vibriones when the screw is slight, and spirochaeta when it has many coils). Besides this threefold difference in the forms of the cytodes, we have a ground of distinction in many bacilli and spirilla in the possession of one or more very thin lashes (flagella), which proceed from one or both poles of the lengthened plastid. The construction and vibration of these serves for locomotion in the swimming bacteria; but they are

only found for a time in many species, and in many others are altogether wanting.

Since, then, neither the simple outer form of the bacterium-cytodes nor their homogeneous internal structure provides a satisfactory ground for the systematic distinction of the numerous species, their physiological properties are generally used for the purpose, especially their different behaviour towards organic foods (albumin, gelatine, etc.), their chemical actions, and the various effects of poisoning and decomposition which they produce in the living organism. No bacteriologist now doubts that all the vital activities of the bacteria are of a chemical nature, and precisely on this account these microbes are of extreme importance. When we bear in mind how complicated are the relations of the various species of bacteria to the tissues of the human body, in which they cause the diseases of typhus, hypochondriasis, cholera, and tuberculosis, we are bound to admit that the real cause of these maladies must be sought in the peculiar molecular structure of the bacterium-plasm, or the particular arrangement of its molecules and the innumerable atoms (more than a thousand) which are, in a very loose way, made up into special groups of molecules. The chemical products of their mutual action are what we call ptomaines, which are partly very virulent poisons (toxins). We have succeeded in producing several of these poisonous matters in large quantities by artificial culture, and isolating them and experimentally ascertaining their nature; as, for instance, tetanin, which causes tetanus, typhotoxin, the poison of typhus, etc.

In thus declaring the action of bacteria to be purely chemical and analogous to that of well-known inorganic poisons, I would particularly point out that this very

justifiable statement is a pure hypothesis; it is an excellent illustration of the fact that we cannot get on in the explanation of the most important natural phenomena without hypotheses. We can see nothing whatever of the chemical molecular structure of the plasm, even under the highest power of the microscope; it lies far below the limit of microscopic perception. Nevertheless, no expert scientist has the slightest doubt of its existence, or that the complicated movements of the sensitive atoms and the molecules and groups of molecules they make up are the causes of the vast changes which these tiny organisms effect in the tissues of the human and the higher animal body.

Moreover, the distinction of the many species of bacteria is of interest in connection with the general question of the nature and constancy of a species. Whereas formerly in biological classification only definite morphological characters, or definable differences in outer form or inner structure, were regarded as of any moment in the distinction of species, here, in view of the vagueness or total lack of these characters, we have to look mainly to the physiological properties, and these are based on the chemical differences in their hypothetical molecular structure. But even these are not absolutely constant; on the contrary, many bacteria lose their specific qualities by progressive culture under changed food-conditions. By a change in the temperature and the nutritive field in which a number of poisonous bacteria have been reared, or by the action of certain chemicals, not only the growth and multiplication are altered, but also the injurious effect they have on other organisms by the generation of poisons. This poisonous effect is weakened, and—what is most important—the weakening is transmitted by heredity to the following

generations. On this is based the familiar process of inoculation, an admirable example of the inheritance of acquired characteristics.

As the bacteria are still often described as "cleavage-fungi" and classified along with the real fungi, we must particularly point out the wide gulf that separates the two groups. The real fungi (or *mycetes*) are metaphyta, their multicellular body (*thallus*) forming a very characteristic sort of tissue, the mycelium; this is composed of a number of interlaced and interwoven threads (or hyphens). Each fungus-thread consists of a row of lengthened cells, which have a thin membrane and enclose a number of small nuclei in the colourless plasm. Moreover, the two sub-classes of the real fungi, the ascomycetes and basimycetes, form peculiar fruit-bodies which generate spores (ascodia and basidia). There is no trace whatever of these real characteristics of the true fungus in the bacteria. Nor is it less incorrect to class them with the fungilli, the so-called unicellular fungi or phycomycetes (ovomycetes and zygomycetes); these form a special class of protists which has the closest affinity to the gregarinæ.

Like the closely-related chromacea, many of the bacteria show a marked tendency to form communities or cell-colonies. These cell-communities arise, as elsewhere, from the fact that the individuals, which multiply rapidly by continuous cleavage, remain joined together. This may happen in two ways. When the social bacteria secrete large quantities of gelatine, and remain distributed in this, we have the *zooglœa* (as in the case of the *aphanocapsa* and *glœocapsa* among the chromacea). If, on the other hand, the long-bodied bacilli remain fastened together in rows, we get the knotted threads of *leptothrix* and *beggiatoa* (which may be compared with the oscillaria).

And, if these threads go into branches, we have *cladothrix*. Other cœnobia of bacteria have the appearance of disks, the cytodes dividing in a plane, usually in groups of four (as in *merismopedia*), or of cube-shaped packets when they are in all three directions of space *(sarcina)*.

The two classes of bacteria and chromacea seem, in the present condition of our knowledge, on account of their simple organisation, to be the simplest of all living things, real monera, or organisms without organs. Hence we have to put them at the lowest stage of the protist kingdom, and must regard the difference between them and the most highly-differentiated unicellular beings (such as the radiolaria, ciliated infusoria, diatomes, or siphonea) as no smaller than the difference (in the realm of the histona) between a lower polyp (*hydra*) and a vertebrate, or between a simple alga (*ulva*) and a palm. But if the kingdom of the protists is badly divided, on the older rule, into a plant kingdom and an animal kingdom, the only discriminating mark we have left is the difference in metabolism; in that case we have to include the plasmophagous bacteria in the animal kingdom (as Ehrenberg did in 1838) and the plasmodomous chromacea in the plant kingdom. The remarkable class of the flagellata, which includes ciliated unicellulars of both groups, contains several forms which are only distinguished from the typical bacterium by the possession of a nucleus. If it is true that in some of the protists which were counted as bacteria a real nucleus has been detected, these must be separated from the others (unnucleated) and included in the nucleated flagellata.

The monera which I described in 1866, and on which I based the theory of the monera in my monograph, belong to a different division of the protists from the classes of bacteria and chromacea. These are the forms

which I described as *protamœba, protogenes, protomyxa,* etc. Their naked mobile plasma-bodies thrust out pseudopodia, or variable "false feet," from their surface, like the (nucleated) real rhizopods (=sarcodinæ); but they differ essentially from the latter in the absence of a nucleus. Afterwards (in my *Systematic Phylogeny*) I proposed to separate these unnucleated rhizopods from the others, giving the name of *lobomonera* (*protamœba*) to the amœba-like monera with flap-shaped feet, and the name of *rhizomonera* (*protomyxa, pontomyxa, biomyxa, arachnula,* etc.) to the gromia-like, root-feet forming monera. However, of late years, real nuclei have been detected in each of these large monera, and so they have been proved to be true cells. This discovery was made possible by the improved modern methods of colouring the nucleus which I had not the use of thirty years ago in my first observations. On the strength of these recent discoveries many scientists claim that all the monera I described are true cells, and must have nuclei. This baseless assertion is much employed by the opponents of the theory of evolution in order to deny the existence of the monera altogether.

Of the genus of monera which we call protamœba I have given an illustration in my *History of Creation* (tenth edition), which has been frequently reproduced. Several species (at least two or three) of this genus still exist, and are distinguished by the shape of their flap-formation and their method of motion. They resemble ordinary simple amœbæ, and only differ from these to any extent in the absence of a nucleus. The *protamœba primitiva* seems to be pretty widely distributed; it has been found repeatedly by observers (Gruber, Cienkowski, Leidy, etc.) in inland waters. In the zoological demonstrations which I have given at the University of Jena

for forty years, and in the course of which the lowly inhabitants of our fresh water are regularly examined with the microscope, the *protamœba primitiva* has been found four or five times. It always had the same form, as I described it, moved about by the slow formation of flaps at its surface, multiplied by simple cleavage, and showed no trace of a nucleus in its homogeneous plasma-body even with the most careful application of the modern methods of tinting the nucleus. A larger number of very fine granules (microsoma) that were irregularly distributed in the plasm, and were more or less coloured by nucleus-reagents, cannot be reckoned as clear equivalents of the nucleus in this or in similar cases; they are probably products of metabolism. The same may be said of the larger marine form of rhizomoneron, which A. Gruber has recently called *pelomyxa pallida*.

The large marine form of rhizomoneron to which Huxley gave the name of *bathybius Hæckelii* in 1868, and as to the real nature of which many opinions have been expressed, seems, according to the latest investigation, not to have the significance ascribed to it. However, the much-discussed question of the bathybius is superfluous as far as our monera theory and the associated hypothesis of archigony (chap. xv.) are concerned, since we have now a better knowledge of the much more important monera-forms of the chromacea and bacteria.

In the case of some of the protists I described in my *Monograph on the Monera*, it is at present doubtful whether their plasma-body contains a nucleus or not, and, therefore, whether they are to be classed as true cells or cytodes. This applies especially to the forms which only happened to come under observation once, such as

*protomyxa* and *myxastrum*. In these obscure cases we must wait for fresh investigations and the application of the modern methods of tinting the nucleus. I may, however, point out, in passing, that these famous methods of nucleus-colouring give by no means the absolute certainty which is ascribed to them; there are other substances which take colour in the same way as chromatin. As far as my monera theory is concerned, or the great general importance which I attach to these unnucleated living granules of plasm, it does not matter whether a nucleus is detected in these problematic monera or not. The chromacea alone—the most important of all monera—completely suffice to provide a base for the far-reaching theoretical conclusions which I draw from it.

At the close of these observations on the monera I will briefly recapitulate the weighty inferences which we can deduce from their simple organisation. They serve as a solid foundation for the chief theses of our monistic biology; and they are inconsistent with the dualistic views of modern vitalists. In the first place, I emphasise the fact that the structureless plasma-body of the simple monera has no sort of organisation and no composition from dissimilar parts co-operating for definite vital aims. Reinke's conscious "dominants"—as well as Weismann's mechanical "determinants"—have nothing to do here. The whole vital activity of the simplest monera, especially of the chromacea, is confined to their metabolism, and is therefore a purely chemical process, that may be compared to the catalysis of inorganic compounds. The simple formation of individuals in this primitive living matter is merely a question of the cleavage of plasma globules of a certain size *(chroococcus)*; and their primitive multiplication (by

simple self-division) is only a continued growth (analogous to that of the crystal). When this simple growth passes a certain limit, that is fixed by the chemical constitution, it leads to the independent existence of the redundant growth-products.

## Chapter X.

# NUTRITION

Functions of nutrition. Assimilation and disassimilation. Plasmodoma and plasmophaga. Phytoplasm and zooplasm. Plasmodomism of plants. Chlorophyll granules and nitro-bacteria. Plasmophagism of fungi and animals. Metasitism (conversion of metabolism). Nutrition of the monera (chromacea, bacteria, rhizomonera). Nutrition of the protophyta and metaphyta (cell-plants and tissue-plants). Nutrition of the metazoa. Gastræa theory. Gastro-canal system of the cœlenteria (gastræads, sponges, cnidaria, platodes). Nutrition of the cœlomaria (digestion, circulation, respiration, evacuation). Saprositism. Parasitism. Symbiosis.

The wonder of life which we call, in the widest sense of the word, "nutrition" is the chief factor in the self-maintenance of the organic individual. It is always bound up with a chemical modification of the living matter, an organic metabolism (circulation of matter), and a corresponding circulation of force. In this chemical process plasm is used up, built up afresh, and once more disintegrated. The metabolism which lies at the root of this chemistry of food is the essential feature in the manifold processes of nutrition. A large part of the several nutritive processes are explained without further trouble by the known physical and chemical properties of inorganic bodies; for another part of them we have not yet succeeded in doing this. Nevertheless, all impartial physiologists now agree that it is possible in principle, and that we have no reason to introduce a special vital principle. All the trophic (nutritive)

processes, without exception, are subject to the law of substance.

In all the higher plants and animals the chemical process of metabolism, with the stream of energy that accompanies it, is a very complex vital activity, in which many different functions and organs co-operate with the common aim of self-maintenance. As a rule, they are distributed in four groups—namely: (1) Intussusception of food and digestion: (2) distribution of the food in the body, or circulation; (3) respiration, or exchange of gases; and (4) excretion of unusable matter. In most of the histona, either tissue-plants or tissue-animals, a number of organs are differentiated for the accomplishment of these tasks. At the lower stages of life this division of labour is not found, the entire process of nutrition being accomplished by a single layer of cells (lower algæ, gastræads, sponges, lower polyps). In the protists, again, it is the single cell that does all these things itself; in the simplest cases, the monera, a homogeneous plasma-globule. As a long gradation uninterruptedly unites these lowest forms of nutrition with the more complicated forms, we must regard the latter no less than the former as physico-chemical processes.

When we take the whole of the metabolic functions in organisms together, we may look upon them as the outcome of two opposite chemical processes—on the one hand the building-up of living matter by taking in food (assimilation), and on the other the breaking-down of it in consequence of its vital activity (disassimilation). As in every case the plasm is the active living matter, we may say: *Assimilation* (or plasma-production) consists in the conversion within the organism into the special plasm of the particular species of food that has been

received from without; *disassimilation* (or plasma-destruction) is the result of the work done by the plasm, which is the cause of its partial decomposition or breakdown. In both respects there is a striking difference between the two great kingdoms of organic nature. The plant kingdom is, on the whole, the agent of assimilation, forming new plasm by synthesis and reduction from inorganic matter. In the animal world, on the contrary, disassimilation preponderates, the plasm received being resolved by oxydation, and the actual energy taken out of it by analysis being converted into heat and motion. Plants are plasmodomous; animals, plasmophagous.

Of all the chemical processes the most important, because the most indispensable, for the origin and maintenance of organic life is the constant re-construction of plasm. We give it the name of plasmodomism (*domeo* = to build-up), or carbon-assimilation. Botanists have the habit of late of calling it briefly assimilation, and have thus caused a good deal of misunderstanding. The more common and older meaning of assimilation in animal physiology is, in the widest sense, the intussusception and preparation of the food received. But the carbon-assimilation in plants—what I call plasmodomism—is only the first and original form of plasma-production. It means that the plant is able, under the influence of sun-light, to form carbo-hydrates, and from these new plasm, out of simple inorganic compounds (water, carbonic acid, nitric acid, and ammonia) by synthesis and reduction. The animal is unable to do this. It has to take its plasm in its food from other organisms—plant-eaters directly, and animal-eaters indirectly. We therefore give the title of *plasmophagous* to these animal "plasma-eaters." In working up the foreign plasm it has eaten, and converting it into its

own specific form of plasm, the animal also accomplishes assimilation; but this animal albumin-assimilation is totally different from the vegetal carbon-assimilation. The fresh-formed animal plasm is then broken up by oxydation, and by this analysis the energy needed for the vital movements is obtained.

The physiological contrast which we thus find between the two principal forms of living matter, the synthetic plasm of the plant and the analytic plasm of the animal, is of great importance for the lasting maintenance of the whole organic world. It depends on a reversal of the molecular movement in the plasm, the intimate nature of which is just as little known to us as the chemical constitution of the albumins in general, and that of living albumin, the plasm, in particular. As I mentioned in chap. v., modern physiological chemistry has good reason to believe that the invisible albumin-molecule is, comparatively speaking, gigantic, and is composed of more than a thousand atoms. These are in such an unstable equilibrium, so complicated and impermanent an arrangement, that the slightest push or stimulus suffices to alter them and form a new kind of plasm. As a fact, the number and variety of kinds of plasm are immense. This is seen at once from the ontogenetic fact that the ovum and sperm-cell of each species (and each variety) have a specific chemical constitution. In reproduction this is transmitted to the offspring. But, setting aside these countless finer modifications, we may distinguish two chief groups of kinds of plasm: the phytoplasm of the plant, with the synthetic property of plasmodomism, and the zooplasm of the animal, which is destitute of this property, and so confined to plasmophagy.

The remarkable synthetic process of building up the

plasm, to which we give the name of plasmodomism, or carbon-assimilation, usually needs as its first condition the radiant energy of sun-light. Every green plant-cell contains in its chlorophyll-granules so many tiny laboratories, their green plasm being able to form new plasm out of inorganic compounds under the influence of light. The water that is needed for this, besides nitrogenous compounds (nitric acid, ammonia), is drawn from the earth by the roots; the carbonic acid is taken from the atmosphere by the green leaves. The immediate products of the synthesis, due to the separation of the carbonic acid, is, as a rule, a non-nitrogenous starch-flour (*amylum*). This is further used for the composition of the nitrogenous albumin by an as yet unknown synthetic process, with the aid of nitrogenous mineral compounds. In this process of reduction the separated free oxygen is returned to the atmosphere. The carbo-hydrates that chiefly co-operate in this are glucoses and maltoses: the mineral substances especially salts of potassium and magnesium, and compounds of these elements with nitric acid, sulphuric acid, and phosphoric acid. Iron is also found to be an important element in the process, though in a very small quantity. As a rule, the ferruginous chlorophyll can only form new plasm with the help of light-waves. The most important part of the spectrum for this purpose is that containing the red, orange, and yellow waves.

The chief factor in plasma-formation in the organic world is the photo-synthesis, or ordinary carbon-assimilation by chlorophyll, the wonderful green matter that amounts to only a very small percentage (about one-tenth) of the weight of the chlorophyll-granules, and can be separated from their plasmatic substance by certain methods. Even when the plant has some other colour

than green the chlorophyll is still the real plasmodomous substance. Its green colour is then masked by some other colour—diatomin in the yellow diatomes, phycorhodin in the red rhodophyceæ, phycophæin in the brown phæophyceæ, and phyocyan in the blue-green chromacea or cyanophyceæ. The latter have an especial interest for us, because in the simplest specimens the entire organism is merely a globular bluish-green granule of plasm. Moreover, in the simplest forms of nucleated primitive plants (*algariæ*)—many of the so-called unicellular algæ—the metabolism is effected by a single grain of chlorophyll. There is usually a large number of them in the plasm of the plant-cells.

Another kind of plasm-synthesis, quite different from the ordinary plasmodomism by chlorophyll and sun-light, has lately been discovered in some of the lowest organisms (by Heraeus, Winogradsky, and others). The nitro-bacteria (or nitromonades) are tiny monera (unnucleated cells) that live in complete darkness underground. Their globular colourless plasma-bodies contain neither chlorophyll nor nucleus. They have the remarkable capacity of forming carbo-hydrates, and from these plasm, by a peculiar synthesis out of purely inorganic compounds—water, carbonic acid, ammonia, and nitric acid. Pfeffer has called this carbon-assimilation, on account of its purely chemical nature, "chemosynthesis," in opposition to the ordinary photosynthesis by means of sun-light. There are also other bacteria (sulphur-bacteria, purple-bacteria, etc.) that show various peculiarities of metabolism. The nitro-bacteria must belong to the oldest monera, and represent a transition from the vegetal chromacea to the animal bacteria.

The extensive class of the fungi (or *mycetes*) resembles a part of the bacteria in regard to metabolism. These

organisms are, it is true, generally regarded as plants, but they have not the capacity of the green, chlorophyll-bearing plants to supply themselves with carbon from the carbonic acid in the atmosphere. They have to take it from organic [substances, such as albumin, carbo-hydrates, etc., like the animals. But while the animals have to derive their nitrogen from the latter, the fungi can obtain it from inorganic matter in the earth. Fungi cannot support life without the addition of organic compounds; but we can make them grow in a food solution consisting of sugar and purely inorganic nitrogenous salts. Thus they are on the border that separates the plasmodomous plants from the plasmo-phagous animals. Like the latter, the fungi have evolved from the plants through changed food conditions. We find this process even among the unicellular protists in the phycomycetes, which descend from the siphonea. In the same way the real multicellular fungi (ascomy-cetes and basimycetes) may be traced to the tissue-forming algæ.

All true animals have to derive their food from the plant kingdom, the vegetal feeders directly, and the flesh feeders indirectly, when they consume vegetal feeders. Hence the animals are, in a certain sense, as the older natural philosophy put it four hundred years ago, "parasites of the plant world." From the point of view of phylogeny, the animal kingdom is, therefore, clearly much younger than the plant kingdom. The develop-ment of the animals from the plants was determined originally by a change in the method of nutrition which we call metasitism.

The chemical modification of the living matter which is connected with the loss of plasmodomism—in other words, the conversion of the reducing phytoplasm into

oxidising zooplasm—must be regarded as one of the most important changes in the history of organic life. This "reversal of metabolism" is polyphyletic; it has been repeated many times in the course of biological history, and has taken place independently in very different groups of the organic world—whenever a plasmodomous cell or group of cells (= tissue) had occasion to feed directly on ready-made plasm, instead of giving itself the trouble of building it up out of inorganic compounds. We see this particularly among the unicellular protists in the independent ciliated cells. The longer plasmophagous flagellata, which are colourless, and have no chlorophyll (monodina, conoflagellata), closely resemble in form and movement the older plasmadomous and chlorophyll-bearing mastigota, from which they are descended (volvocina, peridinia); they only differ in the manner of nutrition. The colourless flagellata feed on ready-formed plasm, which they obtain either by means of their lashes or by a special cell mouth in their cell body. On the other hand, their ancestors, the green or yellow mastigota, form new plasm by photosynthesis like true cells. But there are also complete intermediate forms between the two groups—for instance, the chrysomonades and the gymnodinia; these may behave alternately as protozoa or protophyta. In the same way we can derive the phycomycetes by metasitism from the siphonea, the fungi from the algæ; and, finally, the process is also found in many of the higher parasitic plants (orchids, orobanchs, etc.). (See under "Parasitism.")

As is the case with every other vital function, so for the function of metabolism we find a starting-point in the lowest and simplest group of the protophyta, the chromacea. In their oldest forms, the chroococcacea,

the whole body is merely a blue-green, structureless, globular plasma particle, growing by means of its plasmodomous power, and splitting up as soon as it reaches a certain stage of growth. There the miracle of life consists merely of the chemical process of plasmodomism by photosynthesis. The sun-light enables the blue-green phytoplasm to form new plasm of the same kind out of inorganic compounds (water, carbonic acid, ammonia, and nitric acid). We may look upon this process as a special kind of catalysis. In this case there is absolutely nothing to be done by Reinke's "dominants," or conscious and purposive vital forces. There are, as yet, no differentiated physiological functions in these organisms without organs, and no anatomically distinct members; and so their one vital activity, growth, may very well be compared to the simple growth of inorganic crystals.

It has been pointed out repeatedly that the remarkable monera which now play so important a part in biology as bacteria stand, in many respects, quite apart from the ordinary vital phenomena of the higher organisms. This is especially true of their metabolism, which has the most striking peculiarities. Morphologically, many of the bacteria cannot be distinguished from their nearest relatives and direct ancestors, the chromacea, differing from them only in the absence of colouring matter in the plasm. Many of them are simple, globular, ellipsoid, or rod-shaped plasma particles, without any visible organisation or movement. Others move about by means of one or more very fine lashes (like the flagellata). No real nucleus can be discovered in the structureless plasma body. The very fine granules which are found in some species, and the vacuole-formation that we see in others, may be regarded as products of metabolism;

and the same may be said of the thin membrane or the thicker gelatinous envelope which many of the bacteria secrete. This makes all the more remarkable the peculiarity of their chemical constitution and the metabolism determined thereby. The nitro-bacteria we have mentioned previously are plasmodomous; the anaerobe bacteria (of butyric acid and tetanus) only flourish where oxygen is excluded; the sulphur bacteria *(beggiatoa)* secrete—by the oxydation of sulphuretted hydrogen—pure regulation sulphur in the form of round granules. The ferruginous bacteria *(leptothrix ochrocea)* store up oxyhydrate of iron (by the oxydation of carbonic protoxide of iron). The saprogenetic bacteria cause putrefaction, and the zymogenetic fermentation. Finally, we have the very interesting pathogenetic bacteria which cause the most dangerous diseases by the secretion of special poisons—toxins—festering, small-pox, tetanus, diphtheria, typhus, tuberculosis, cholera, etc. On account of their great practical importance, these bacteria have of late been taken over by a special branch of biology, bacteriology. But only a few of the many experts in this department have pointed out the extreme theoretical significance which these zoomonera have for the important questions of general biology. These structureless plasma bodies show unmistakeably that their vital activity is a purely chemical phenomenon. Their great variety proves how manifold and complicated must be the molecular composition of the plasm, even in these simplest organisms.

The unicellular protophyta exhibit the same form of metabolism and plasmodomism as the familiar green cells of the tissue-plants; but in most of the protozoa we find special features of nutrition and plasmophagy. The great class of the rhizopods is distinguished by the fact

that their naked plasma body can take in ready-formed solid food at any point of its surface. On the other hand, most of the infusoria have a definite mouth-opening in the outer wall of their unicellular body, and sometimes a gullet-tube as well. Besides this cell-mouth *(cytostoma)* we usually find also a second opening for the discharge of indigestible matter, a cell-anus *(cytopyge)*.

Metabolism in the tissue plants (metaphyta) forms a long gradation from very simple to very complicated arrangements. The lowest and oldest thallophyta, especially the simplest algæ, are not far removed from the communities of protophyta, and, like these, are merely definitely grouped colonies of cells. The social cells which form their most rudimentary tissue are quite homogeneous, with no differentiation beyond that of sex. The thallus or bed-formation consists in the simplest specimens of plain or branched fine threads, consisting of rows or chains of homogeneous cells (so *conferva* among the green, *ectocarpus* among the brown, and *callithamnion* among the red algæ). Other algæ (such as the *ulva*) form thin leaf-shaped forms of the thallus, a number of homogeneous cells lying side by side along a level. In the larger algæ compact tissue-bodies are formed, in which frequently firmer rows of cells exhibit the rudiments of fibres; and the thallus divides, as in the cormophyta, into root, stalk, and leaves. There is also a trophic differentiation, the fibres undertaking special functions of nutrition (the conduction of the sap). The same must be said of the mosses *(bryophyta)*. Their lowest forms *(ricciadinæ)* are close akin to the algæ; the highest mosses (the *mnium* and *polytrichum*, for instance) approach the cormophyta. Many botanists comprise these lower plants—algæ,

fungi, and mosses—under the title of "cell-plants" *(cytophyta)*, and oppose the higher plants—ferns and flowering-plants—to them as "vascular plants" *(angiophyta)*, because they have complex fibres or sap vessels. This distinction has a phylogenetic significance similar to the division between cœlenteria and cœlomaria in the animal kingdom.

While most of the cell plants either live in the water (algæ) or are very simply organised on account of their saprophytic or parasitic habits (fungi), the vascular plants mostly live on land, and have to adapt themselves to much more complicated conditions. Their nutrition is accordingly distributed among different functions, and special organs have been evolved to discharge them. This is equally true of the crytogam ferns *(pteridophyta)* and the phanerogam flowering plants *(anthophyta)*. The most important later acquisition which distinguishes both groups from the lower cell plants is the possession of vascular or conducting fibres. These organs for conducting water pass through the entire body of the vascular plant in the shape of long tubes, formed by the combination of rows of cells; the cells themselves die off, and their plasma content disappears. The stream of water that rises constantly in these tubes is taken up by the roots, conducted by the fibres to all parts, and given off (transpiration) by the pores of the leaves. But these pores also serve for the breathing of plants, being connected with the air-containing intercellular passages; through these air spaces, which serve for the aeration of the higher plant body, air and moisture can enter, and oxygen be given off in respiration. Finally, many of the vascular plants have special glands that serve for secretion (of oil, resin, etc.). In the higher flowering plants this division of work among the various digestive

organs gives rise to a very complicated apparatus for nutrition. Among the many remarkable structures that have been developed in this way by adaptation to special conditions we may particularly note the organs for catching and digesting insects in the insect-eating plants, the European *drosera* and *utricalaria*, and the tropical *nepenthas* and *dionœa*.

The long scale of evolutionary forms which we find in the tissue animals (metazoa) leads up uninterruptedly from the simplest to the most elaborate physiological functions and a corresponding morphological complexity of organs. The two principal divisions of the metazoa are chiefly distinguished by the circumstance that in the cœlenteria one single system of organs, the gastro-canal system, discharges the whole (or most part) of the partial functions of nutrition; while in the cœlomaria they are usually distributed among four different systems of organs, each of which is made up of a number of organs. To an extent, we find once more in each great division characteristic types of organisation. However, comparative ontogeny teaches us that all these various structures have been developed from one simple fundamental form, as I have shown in my theory of the gastræa (1872).

The older research into the origin of the nutritive apparatus in the metazoa—especially its chief part, the alimentary or gastric canal—had led to the erroneous belief that in several groups of the metazoa it owed its origin to very different growth-processes, and that particularly in the higher vertebrates (the amniotes) it was a comparatively late product of evolution. On the other hand, the comparative study of the embryology of the lower and higher animals led me thirty-four years ago to the opposite conclusion, that a simple gastric sac was the first and oldest organ of all the metazoa, and

that all the different forms of it had been developed from this primitive type. I gave this view in my *Biology of the Sponges* in 1872; and I developed and established it in my *Studies of the Gastræa Theory* in 1873. In the latter book I also worked out the important conclusions that follow from this monistic reform of the theory of germinal layers for the phylogenetic natural classification of the animal kingdom. I began with the consideration of the simplest sponges *(olynthus)* and cnidaria *(hydra)*. The whole body of these lowest and oldest of the cœlenteria is in essence nothing but a round, oval, or cylindrical gastric vesicle, a digestive sac, the thin wall of which consists of two simple layers of cells. The outer layer (the ectoderm or skin-layer) is the covering layer of the external skin (epidermis); it is the instrument of sensation and movement. The inner layer of cells (entoderm or gastric layer) serves for nutrition; it clothes the simple cavity of the sac, which admits the food by its opening and digests it. This opening is the primitive mouth *(prostoma* or *blastoporus)*, the inner cavity itself the primitive gut *(progaster* or *archenteron)*. I proved that there was the same composition in the young embryos or larvæ of many of the lower animals, and showed that the manifold and apparently very different embryonic form of all the higher animals may be reduced to the same common type. To this I gave the name of the "cup-embryo" or gastric larvæ *(gastrula)*, and concluded, in virtue of the biogenetic law, that it is the palingenetic reproduction of a corresponding ancestral form (the *gastræa*) maintained until the present by heredity. It was not until much later (1895) that Monticelli discovered a modern gastræad *(pemmatodiscus)* which corresponds completely to this hypothetical ancestor (see the last edition of my

*Anthropogeny*, Fig. 287). The simplest living forms of the sponges *(olynthus)* and the cnidaria *(hydra)* only differ from this hypothetical primitive form of the gastræa by a few secondary and subsequently acquired features.

The classes of the lower animals which we comprise under the name cœlenteria (or cœlenterata in the widest sense) generally agree in having all the functions of nutrition accomplished exclusively (or for the most part) by a single system of organs, the gastro-canal or gastro-vascular system. From their common stem-group, the gastræads, three different stems have been evolved—the sponges, cnidaria, and platodes. All these cœlenteria have three features in common: (1) The gastric canal or tube has only one opening—the primitive mouth, which serves at once for admitting food and ejecting indigestible matter; there is no anus; (2) there is no special body-cavity (*cœloma*) distinct from the gastric tube; (3) there is also no trace of a vascular system. All cavities that are found in these lower animals besides the digestive gut-cavity are direct processes from it (with the exception of the nephridia in the platodes).

While the simple digestive gut is the sole organ of nutrition in the stem-group of the gastræads, we find other structures co-operating in the rest of the cœlenteria. The characteristic stem of the sponges is distinguished by the piercing of the wall of the gastric vesicle with several holes. Through these water pours into the body, bringing with it the small particles of food which are received and digested by the ciliated cells of the entoderm; the water emerges again by the mouth-opening *(osculum)*. The best-known of the sponges is the common bath sponge *(euspongia officinalis)*, the horny skeleton of which we use daily in washing. In these and most other

sponges the large unshapely body is traversed by a number of branching canals, on which there are thousands of tiny vesicles, produced by the multiplication of a simple gastric vesicle of the primitive sponge *(olynthus)*. Each of these ciliated chambers is really a tiny gastræa, a "person" of the simplest character (*cf.* chap. vii.). Hence we may regard the whole sponge-body as a gastræad-stock *(cormus)*.

The large group of the cnidaria offers a long series of evolutionary stages, from very small and simple to very large and elaborate forms. Some of them remain at a very low stage, as does our common green fresh-water polyp *(hydra viridis)*, which only differs from the gastræa by a few variations in tissue and the formation of a crown of feelers about the mouth. Most of the polyps form stocks *(cormi)*, the individuals shooting out buds which remain joined to the mother animal. In these and all the other stock-forming animals the nutrition is communistic; all the food that the individuals get and digest is conducted by tubes to the common fund and equally distributed. In all the larger cnidaria the body-wall becomes thicker, and is traversed by branching gastro-canals; these convey the nutritive fluid to all parts of the body.

While the fundamental type in the cnidaria is radial (determined by the crown of radiating feelers or tentacles that surrounds the mouth), it is bilateral-symmetrical in the platodes or "flat-worms" *(plathelminthes)*. In this animal-stem, moreover, the lowest forms, the platodaria (also called *cryptocœla* and *acœla*) come very close to the gastræa. But most of the platodes are distinguished from the rest of the cœlenteria by the formation of a pair of nephridia (renal canals or water-vessels), thin tubes which, as excretory organs, remove from the body the

unusable products of metabolism, the urine. Here we have a second organ of nutrition, the gut tube, added to the first. In the lower platodes this remains very simple. As a rule, a gullet tube (pharynx) is formed by the hollowing out of the mouth, as in the corals; and as in the case of the latter branched canals, which conduct the nutritive sap from the stomach to distant parts of the body, grow out of the stomach, in the larger coil-worms *(turbellaria)* and suction-worms *(trematodes)*. On the other hand, the gut atrophies in the tape-worms *(cestodes)*; as these parasites live in the intestines or other organs of animals, they can obtain their nutritive sap directly from them through the surface of the skin.

The more highly organised cœlomaria differ from the simpler cœlenteria chiefly by the greater complexity in the structure and functions of their apparatus of nutrition. As a rule, these functions are divided between four groups of organs, which are not yet differentiated in the cœlenteria—namely: 1, organs of digestion (gastric system); 2, organs of circulation (vascular system); 3, organs of breathing (respiratory system); and 4, organs of excretion (renal system). Moreover, in the cœlomaria the gastric canal has usually two openings, the mouth and the anus. Finally, they all have a special body-cavity *(cœloma)*; this is quite separate from the gastric canal, which is suspended in it, and serves for the formation of the sexual cells. It is formed in the embryo by the hollowing out and cutting off of a pair of sacs (cœlom-pouches) from the gut near the mouth; the pouches touch, and then coalesce, as their division-walls break down. If a part of the dividing wall remains, it serves as mesentery to fasten the gut to the body-wall. The action of the four groups of alimentary organs remains very simple in the

lowest and oldest cœlomaria, the worms *(vermalia)*; but in the other higher animals, which have been evolved from these, they have very varied and often complicated features.

In the great majority of the cœlomaria the gastric system forms a highly differentiated apparatus, composed, as in man, of a number of different organs. The food is usually taken in by the mouth, ground up by the jaws or the teeth, and softened with saliva, which the salivary glands pour into the cavity of the mouth. From the mouth the pulpy food passes in swallowing into the gullet, which often has glandular appendages, and from this through the narrow œsophagus into the stomach. This most important part of the alimentary apparatus is often divided into several sections, one of which (the masticating stomach) is armed with teeth and prepared for a further triturition of solid pieces, while the other (the glandular stomach) produces the dissolving gastric juice. The liquified food *(chylus)* then passes into the small intestine *(ileum)*, which has to absorb it, and is as a rule the longest section of the alimentary canal. A number of different digestive glands open into this intestine, the most important of them being the liver. The small intestine is often sharply distinguished from the large intestine *(colon)*, the last large section of the alimentary canal; into this also a number of glands and blind intestines open. The last portion of it is called the *rectum*, and this removes the indigestible remnants of the food *(fæces)* through the anus.

This general plan of the alimentary system, which is common to most of the cœlomaria in its chief features, is very much modified in the various groups of these animals and adapted to their several conditions of

nutrition. The simplest structures are found in many of the vermalia; the lowest forms of these, the rotifers, and especially the gastrotricha, still closely resemble their platode ancestors, the turbellaria. The higher type of animal-stems which have been evolved from them are partly distinguished by special structures. Thus the molluscs have a characteristic masticating apparatus; on their tongue there is a hard plate *(radula)* armed with a number of teeth, which grinds against a hard upper jaw, and so breaks up the food. In most of the articulates this work is done by side-jaws, which consist of hard rods and represent modified bones. The vertebrates and the closely related tunicates are distinguished by the conversion of the first sections of the alimentary canal into a characteristic respiratory apparatus (gills). But the construction of the various sections of the gastro-canal also varies a good deal in the smaller groups of the cœlomaria, as it depends to a great extent on the nature of the food and the conditions in which it is got and prepared. The largest expenditure of mechanical and chemical energy is needed for a voluminous solid vegetal diet. Hence the alimentary canal and its many appendages are longest and most complicated in the plant-eating snails, leaf-eating insects, and grass-eating ruminants. On the other hand, they are shortest and simplest in parasitic cœlomaria, which derive their fluid food already prepared from the contents of another animal's intestines. In these cases the gut may altogether atrophy; as in the *acanthocephala* among the vermalia, the *entoconcha* among the molluscs, and the *sacculina* among the crustacea.

The greater the extent of the body, and the more complex the organisation of the higher animals, the more necessary it is to have an orderly and regular distribution of the nutritive fluid to all parts. In the cœlenteria

this work is accomplished by the gastric canals (side branches from the gut, opening into its cavity), but in the cœlomaria it is done much better by means of blood-vessels *(vasa sanguifera)*. These canals do not communicate directly with the gastro-canal, but are formed independently of it in the surrounding parenchyma of the mesoderm. They take up the filtered and chemically improved food-fluid, which transudes through the intestinal walls, and conduct it in the form of blood to all parts of the body. This blood generally contains millions of cells, which are of great importance in metabolism. The blood-cells of the lower cœlomaria are usually colourless (leucocytes), while those of the vertebrates are mostly red (rhodocytes).

The circulation of the blood in most of the cœlomaria is effected by a heart, a contractile tube, formed by the local thickening of a skin-vessel, which contracts and beats regularly by means of its muscular bands. Originally two of these skin-vessels were developed in the abdominal wall—a dorsal vessel in the upper and ventral vessel in the lower wall (as in many of the vermalia). The heart is formed from the dorsal vessel in the molluscs and articulates, but from the ventral in the tunicates and vertebrates. The arteries are the vessels which conduct the blood from the heart; those which conduct it from the body to the heart are the veins. The finest branchlets of both kinds of vessels, which form the connecting link between them, are called capillaries; these immediately effect the interchange of matter in the tissues by osmosis. The blood-vessels co-operate very closely with the respiratory organs.

The interchange of gases in the organism which we call breathing or respiration—the taking in of oxygen and

giving out of carbonic acid gas—does not require special organs in the lower animals. In these it is accomplished by epithelial cells, which clothe the surface of the body —the ectoderm of the outer skin layer and the entoderm of the inner gut covering. As nearly all these cœlenteria live in the water, or (as parasites) in some fluid that contains air, and as these fluids are constantly pouring in and out of the body, the exchange of gases is accomplished at the same time. But in the higher animals this is rarely found, only in the small animals of simple construction (such as the rotifers and other vermalia, and the smallest specimens of the mollusca and articulata). The majority of these cœlomaria attain a considerable size, and so require special organs; these afford a larger surface for the exchange of gases in the limited space, and accomplish a very peculiar chemical work as the localised organs of respiration. They fall into two groups according to the nature of the environment: gills for breathing in water and lungs for breathing on land. The latter take the oxygen directly from the atmosphere, and the former from the water, in which atmospheric air is contained in solution.

The instruments of water-respiration which we call gills *(branchiæ)* are generally attenuated parts or processes of the outer skin or the inner gastric skin; hence we distinguish the two chief forms, external and internal gills. Both are richly provided with blood-vessels which bring the blood from the body for the purpose of aeration. Cutaneous or external gills are especially found in the vertebrates, in the form of threads, combs, leaves, pencils, tufts of feathers, etc., which are drawn out from the entoderm as local processes of the outer skin, and afford a wide surface for the interchange of gases between the body and the

water. In the mollusca there are usually a pair of comb-shaped gills near the heart; in the articulates there are several pairs, repeated in the different segments of the body. Gastric or internal gills are peculiar to the vertebrates and the next-related tunicates, with a small group of the vermalia, the enteropneusta. In these the fore-gut or head-gut is converted into a gill-organ, the wall of which is pierced with gill-fissures; the water that has been taken in by the mouth passes away through the outer openings of these fissures. In the lower aquatic vertebrates (acrania, cyclostoma, and fishes) the gills are the sole organs of breathing; in the higher animals, that live in the air, they fall into disuse, and their place is taken by lungs. Nevertheless, heredity is so tenacious that we find from three to five pairs of rudimentary gill-clefts in the embryo right up to man, though they have long since ceased to have any function. This is one of the most interesting of the palingenetic facts that prove the descent of the amniotes (including man) from the fishes.

The group of the aquatic echinoderms has some very peculiar features of respiration. Their body possesses an extensive water-duct, which takes in the sea-water and returns it by special openings (skin-pores or madreporites). The many branches of these water-vessels or ambulacral vessels fill with water, especially the tiny feelers or feet, which extend from the skin in thousands; they serve at once for movement, feeling, and breathing. But many of the echinoderms have also special gills—the star-fish have small finger-shaped cutaneous gills on the back, the sea-urchins special leaf-shaped ambulacral gills, the sea-cucumbers internal gastric gills (tree-shaped branching internal folds of the rectum).

The organs of air-breathing are called, in general,

lungs *(pulmones)*. Like the organs of water-breathing, they are formed sometimes from the external and sometimes from the internal covering of the body. Cutaneous or external lungs are found in several groups of the vertebrates. Among the molluscs the land-dwelling lung-snails have acquired a lung-sac by change in the work of the gill cavity: among the articulata the lung-spiders and scorpions have two or more trachea-lungs; that is to say, cutaneous sacs, in which are enclosed fan-wise a number of trachea-leaves. In the other air-breathing articulates (tracheata) we find, instead of these simple or branched, and often bush-like, air tubes *(tracheæ)*, which spread through the whole body and conduct the air direct to the tissues. They take the air from without by special air-holes in the skin *(stigmata* and *spiracula)*. The myriapods and insects generally have numbers of air-holes; the spiders only one or two, more rarely four, pairs. When these air-tube animals return to an aquatic life (as happens with the larvæ of various groups of insects), the outer air-holes close up, and new thread-shaped or leaf-shaped trachea-gills are formed, which take the air from the surrounding water by osmosis. The oldest and lowest tracheata are the primitive air-tube animals, or protracheata, and form the link between the older annelids and the myriapods. They have a number of clusters of short air-tubes distributed over the whole skin, and it is clear that these have been evolved from simple skin-glands by change of function.

Gastric or internal lungs are only found in the higher animals, to which we give the name of quadrupeds (or *tetrapoda)*, the amphibia and amniotes, and their fish-like ancestors, the dipneusta. These internal lungs are sac-shaped folds of the fore-gut, formed originally from the swimming-bladder *(nectocystis)* of the fishes by

change of function. This air-filled bladder, a sac-shaped appendage of the gullet, merely serves the purpose of a hydrostatic organ, by varying the specific weight, in the fishes. When the fish wishes to descend it contracts the bladder and becomes heavier; it rises to the top by inflating it again. The lungs were formed by the adaptation of the blood-vessels in the wall of the swimming-bladder to the interchange of gases. In the oldest living lung-fishes *(ceratodus)* it is still a simple sac *(monopneumones* = one-lunged); in the others the simple gullet-cavity divides early into a pair of sacs *(dipneumones*, two-lunged). The wind-pipe *(trachea*—not to be confused with the organ of the same name in the tracheata) is formed by the lengthening of their stalk and strengthening of it with cartilaginous rings. At the anterior end of the trachea we find already formed in the amphibia the larynx, the important organ of voice and speech.

The function of removing unusable matter is not less important to the organism than breathing. Just as breathing gets rid of the poisonous carbonic acid, so the kidneys remove fluid and solid excreta in the shape of urine; these are partly acid (uric acid, hippuric acid, etc.), partly alkaline (urea, guanine, etc.). In most of the cœlomaria special organs for removing these would be superfluous, as this is accomplished (like breathing) by the stream of water that is constantly passing through the whole body. But with the platodes we begin to find important excretory organs in the nephridia, a pair of simple and ramified canals which lie on either side of the gut, and open outwards. These primitive renal canals are transmitted by the platodes to the vermalia, and by these to the higher stems of the cœlomaria. In the latter they generally open by special funnels into the

inner body-cavity, which serves as first receptacle for the urine. Their outer opening sometimes (primarily) goes through the outer skin at the back (excretory pores), sometimes (secondarily) to the rectum, and so out through the anus. The oldest articulates, the annelids, have a pair of nephridia in each segment of the body; each renal canal, or segmental canal, consists of three sections, an inner funnel which opens into the body cavity, a middle glandular section, and an external bladder that ejects the urine by contraction. The disposition of the renal system in the internally articulated vertebrates is very similar to this; but now complicated structures begin to appear, a pair of compact kidneys *(renes)*, which are made up of a number of branching nephridia. Three generations of kidneys succeed each other, as phylogenetic stages of evolution—first the primary fore-kidneys *(protonephros)*, in the middle the secondary primitive kidneys *(mesonephros)*, and last the tertiary after-kidneys *(metanephros)*. The latter are only reached in the three highest classes of vertebrates, reptiles, birds, and mammals. Molluscs also have a couple of compact kidneys. They are developed from a pair of nephridia, the funnels of which open internally into the heart-pouch (the remainder of the reduced body-cavity); at the back they open outwards. The crustacea also have generally a pair of renal canals. On the other hand, the protracheata (the stem-forms of the air-tube animals) have segmental nephridia, a pair to each joint, inherited from their annelid ancestors. The rest of the tracheata, the myriapods, spiders, and insects, have, instead of these, Malpighi tubes, funnel-shaped glands that arise from the entodermal rectum, sometimes one pair or less, sometimes a number in a cluster.

While most plants are purely plasmodomous, and most animals plasmophagous, there are nevertheless in both organic kingdoms a number of species (especially the lower) whose metabolism has assumed peculiar forms by their relations to other organisms. To this class belong especially the saprosites and parasites. By saprosites are understood those plants and animals which feed entirely or mostly on the corpses of other animals, or the decomposed matter which is unfit for the food of higher animals. Among the unicellular protists many of the bacteria, especially, belong to this class, and also many fungilla *(phycomycetes)*; among the metaphyta the fungi (mycetes), and among the metazoa the sponges. I have already spoken of the many peculiarities of metabolism in the ubiquitous bacteria; while many of them cause putrefaction, they at the same time feed on the parts of other organisms which have died. The fungi feed for the most part on the decayed remains of plants and the products of putrefaction which accumulate on the ground. In this character of scavengers they play the same important part on land as the sponges do at the bottom of the sea. But a number of small groups of the higher plants and animals have, as a secondary habit, turned to saprositism. Among the metaphyta we have especially the monotropea (to which our native asparagus, *monotropa hypopitys*, belongs) and many orchids *(neottia, corallorhiza)*. As they find their plasm directly in the decayed matter in the woods, they have lost their chlorophyll and green leaves. Among the metazoa many of the vermalia, and some of the higher animals, such as the rain-worm and many tube-dwelling annelids (the mud-eaters, *limicolæ*), etc., live on putrid matter. The organs which their nearest relatives use

for obtaining, breaking up, and digesting food (eyes, jaws, teeth, digestive glands) have been entirely or mostly lost by these saprosites. Many of them form a transitional type to the parasites.

By parasites, in the narrower sense, we understand, in modern biology, only those organisms which live on others and derive their nourishment from them. They are numerous in all the chief divisions of the plant and animal kingdoms, and their modifications are of great interest in connection with evolution. No other circumstance has so profound an influence on the organism as adaptation to a parasitic existence. Moreover, there is no other section in which we can follow, step by step, the course of the degeneration which is caused, and show clearly the mechanical nature of the process. Hence the science of parasites—parasitology—is one of the soundest supports of the theory of descent, and provides an abundance of the most striking proofs of the much-contested inheritance of acquired characteristics.

Among the unicellular organisms, the bacteria are the most conspicuous instances of manifold adaptation to parasitic habits. As we count these unnucleated protozoa among the oldest and simplest organisms, and trace them directly by metasitism to the plasmodomous chromacea, it is very probable that they turned to parasitism very early in the history of life. Even a part of the monera (in which group we must place the bacteria on account of their lack of a nucleus) found it convenient and advantageous to prey on other protists and assimilate their plasm directly, instead of going through the laborious process of carbon assimilation themselves in the hereditary fashion. This is also true of the large class of the sporozoa or fungilla (*gregarinæ*, *coccidia*, etc.), real nucleated cells, which have adapted

themselves in various ways to parasitic habits. Many of them live in the rectum, the cœlum, or other organs of the higher animals (the gregarinæ, especially in the articulates); others in the tissues (for instance, the sarcosporidia in the muscles of mammals, the coccidia and myxosporidia in the liver of vertebrates). A good many of them are "cell-parasites," and live inside the cells of other animals, which they destroy; such are the hœmosporidia, which destroy the blood-cells in man, and so cause intermittent fever.

Among the multicellular metaphyta it is particularly the fungi that have taken to parasitism in various ways. Many of them are, as is known, the most dangerous enemies of the higher animals and plants. The various species of fungi cause certain diseases by their poisonous (chemical) action on the tissues of their host. It is well known how our most important cultivated plants, the vine, potato, corn, coffee, etc., are threatened by fungoid diseases; and this is also true of many of the lower and higher animals. It is probable that the fungi have been evolved polyphyletically by metasitism from the algæ.

Among the higher metaphyta we find parasitism in many different families, especially orchids, rhinanthacea *(orobranche, lathraca)*, convolvulacea *(cuscuta)*, aristolochiacea, loranthacea *(viscum, loranthus)*, rafflesiacea, etc. These various kinds of flowering-plants often grow to resemble each other by convergence (that is to say, by their common adaptation to parasitic life); they lose their green leaves, the plasmodomous chlorophyll of which is of no further use to them. Frequently rudimentary leaves are left on them in the form of colourless scales. For the purpose of clinging to the plants they live on, and penetrating into their tissues, they evolve special clinging apparatus (haustoria, suctorial cups,

creepers). Their stalks and roots are also modified in a characteristic way. The whole productive force of these parasites is expended on their sexual organs; *rafflesia* has the largest flowers there are, more than a yard in diameter.

Parasitism in the metazoa (in all groups) is even more frequent and interesting than in the metaphyta. The molluscs and echinoderms show the least disposition for it, and the platodes, vermalia, and articulates the most. Even among the gastræada, the common ancestral group of the metaphyta, we find parasites (kyemaria and gastremaria). The protection they find inside their hosts is probably the reason why these oldest of the metazoa have remained unchanged to the present day. Real parasites are not numerous among the sponges and cnidaria. But they are very numerous among the platodes. The suctorial worms *(trematodes)* live partly externally (as ectoparasites) on other animals and partly inside them (as endoparasites), and produce serious diseases in them. They have lost the vibratory coat of their free-living ancestors, the turbellaria, and acquired clinging apparatus instead. The tape-worms *(cestodes)*, which live entirely in the interior of other animals, and are descended from the suctorial worms, have lost their gastro-canal; they are nourished by imbibition through the skin. The same degeneration is found in the itch-worms *(acanthocephala)* among the vermalia, the parasitic snails *(entoconcha)* among the molluscs, and the root-crabs *(rhizocephala)* among the crustacea.

The class of crustacea affords the most numerous and most instructive examples of degeneration through parasitism, because in this class it is found polyphyletically in very different orders and families, and because their highly-organised body shows every stage of degeneration together in the different organs. The

free-living crustacea generally move about very rapidly and ingeniously; their numerous bones are well jointed and excellently adapted for the most varied methods of locomotion (running, swimming, climbing, digging, etc.); their organs of sense are highly developed. As these are no longer used when they take to parasitism, they atrophy and gradually disappear. The younger crustacea all proceed from the same characteristic form of the *nauplius*, and swim freely about; later, when they settle down to parasitic habits, their organs of sense and locomotion atrophy. As Fritz Müller-Desterro showed in his famous little work, *For Darwin* (1864), forty years ago, the crustacea afford most luminous proofs of the theory of descent and selection, and of progressive heredity and the biogenetic law. These facts are the more important as the crab undergoes the same degeneration by parasitic habits in a number of different orders and families.

From parasitism we must entirely distinguish that intimate life-union of two different organisms which we called symbiosis or mutualism. Here we have an association of two living things for their mutual benefit, while the parasite lives entirely at the expense of his host. Symbiosis is found among the protists, being very widespread among the radiolaria. In the gelatinous envelope *(calymma)* which encloses the central capsule of their unicellular bodies we find a number of motionless yellow cells *(zooxanthella)* scattered. These are protophyta or (as it is said) "unicellular algæ" of the class of paulotomea *(palmellacea)*. They receive protection and a home from the radiolaria, grow plasmodomously, and multiply by rapid segmentation. A large part of the starch-flour and the plasm which they form by carbon-assimilation goes as food directly to the radiolarium-host;

the other part of the xanthella goes on growing and multiplying. Similar yellow zooxanthella or green zoochlorella are found as symbionta in the tissues of many animals. Our common fresh-water polyp *(hydra viridis)* owes its green colour to the zoochlorella which live in great numbers on the ciliated cells of its entoderm (the digestive gut-epithelium). In general, however, symbiosis is rarer in the metazoa than in the metaphyta. In the latter case it is the fundamental feature of a whole class of plants, the lichens. Each lichen consists of a plasmodomous plant (sometimes a protophyte, sometimes an alga) and a plasmophagous fungus. The latter affords a home, protection, and water to the green alga, which repays the service by providing food.

## Chapter XI.

# REPRODUCTION

Reproduction and generation. Sexual and asexual reproduction. Superfluous growth. Monogony. Self-cleavage. Budding. Formation of spores. Amphigony. Ovum and sperm cell. Hermaphrodite formation and separation of the sexes. Hermaphrodism and gonochorism of the cells. Monoclinism and diclinism. Monœcism and diœcism. Alternation of sex-division. Sexual glands of the histona. Hermaphroditic glands. Sexual ducts. Generative organs. Parthenogenesis. Pædogenesis. Metagenesis. Heterogenesis. Strophogenesis. Hypogenesis. Hybridism. Generation of hybrids and the species. Graduation of forms of reproduction.

While nutrition secures the maintenance of the organic individual, reproduction ensures that of the organic species, or the group of definite forms which we distinguish from others by the name "species." All individuals are more or less restricted in the duration of their lives, and die off after the lapse of a certain time. The succession of individuals, connected by reproduction and belonging to a species, makes it possible for the specific form itself to last for ages. In the end, however, the species is temporary; it has no "eternal life." After existing for a certain period, it either dies or is converted by modification into other forms.

The rise of new individuals by reproduction from parent organisms is a natural phenomenon with definite time-restriction. It cannot have continued from eternity on our planet, as the earth itself is not eternal, and even long after its formation was incapable of supporting

organic life on its surface. This only became possible when the surface of the glowing planet had sufficiently cooled for liquid water to settle on it. Until this stage carbon could not enter into those combinations with other elements (oxygen, hydrogen, nitrogen, and sulphur) which led to the formation of plasm. As I intend to deal with this process of *archigony*, or spontaneous generation, in a special chapter, I leave it for the present, and confine myself to the study of *tocogony*, or parental generation.

The various forms of tocogony, or the reproduction of living things, are generally divided into two large groups; on the one hand there is the simple form of asexual generation (monogony), and on the other the complex form of sexual generation (amphigony). In asexual generation the action of one individual only is needed, this providing a product of transgressive (redundant) growth which developes into a new organism. In sexual generation it is necessary for two different individuals to unite in order to produce a new being from themselves. This amphigony (or *generatio digenea)* is the sole form of reproduction in man and most of the higher animals. But in many of the lower animals and most of the plants we find also asexual multiplication, or monogony, by cleavage or budding. In the lowest organisms, the monera, and many of the protists, fungi, etc., the latter is the only form of propagation.

Strictly speaking, monogony is a universal life-process; even the ordinary cell-cleavage, on which depends the growth of the histona, is a cellular monogony. Hence historical biology must say that monogony is the older and more primitive form of parental generation, and that amphigony was secondarily developed from it. It is

important to emphasise this because, not only some of the older writers, but even some recent ones, regard sexual generation as a universal function of organisms, and declare that it dates from the very beginning of organic life.

The complex and frequently very intricate phenomena of sexual generation, as we find them in the higher organisms, become intelligible to us when we compare them with the simpler forms of asexual generation at the lowest stages of life. We then learn that they are by no means unintelligible and supernatural marvels, but natural physiological processes, which, like all others, may be traced to the action of simple physical forces. The form of energy which lies at the root of all tocogony is *growth (crescentia)*. And as this phenomenon is also the cause, in the form of gravitation, of the formation of crystals and other inorganic individuals, we do away with another of the boundaries which people would establish between organic and inorganic nature. Reproduction is a kind of nutrition and growth of the organism beyond the individual standard, building up a part of it into a whole. This *limit* of individual size is determined for each species by two factors—the inner constitution of the plasm, which is inherited, and the dependence on the outer environment, which controls adaptation. When this limit has been passed, the transgressive growth takes the form of reproduction. Every species of crystal has also a definite limit of growth; when this is passed, new crystal-individuals are formed in the mother-water on the old individual, which grows no further.

Asexual or monogenetic tocogony (also called "vegetative multiplication") is always effected by a single organic individual, and so must be traced to its transgressive growth. When this affects the entire body as a total

growth, the whole dividing into two or more equal parts, we call the monogenetic process division (or segmentation). But when the growth is partial, and affects only a part of the individual, or when this special part separates from the generating organism in the form of a bud *(gemma)*, the process is called budding or gemmation *(gemmatio)*. Hence the essential difference between the two forms of generation is that in division the parent disappears in its partial products (children); these are of the same age and form. But in budding the generating parent retains its individuality; it is larger and older than the young bud. This important difference between division and gemmation, which is often overlooked, holds good both for protists (unicellulars) and histona (multicellulars). The fact that in division the individual as such is destroyed is a sufficient refutation of Weismann's theory of the immortality of the unicellulars. (See above, and also the *Riddle*, chap. xi.)

Reproduction by division is by far the most common of all forms of propagation. It is the normal form of monogony, not only in many of the protists, but also in the tissue-cells which compose the tissues of the histona. It is, moreover, the sole method of propagation for most of the monera, both chromacea and bacteria, which are in consequence often comprised under the title of "cleavage-plants" *(schizophyta)*. Self-cleavage is also found among the higher multicellular organisms—namely, the cnidaria (polyps, medusæ). It usually takes the form of division into two ports *(dimidiatio* or hemitomy), the body splitting into two equal halves. The plane of division is sometimes indefinite (fragmentary-cleavage), sometimes coincident with the long axis (length-cleavage), sometimes with the transverse axis, vertical to the long axis (transverse-cleavage), and less

frequently with a diagonal axis (oblique-cleavage). When the segmentation of a cell proceeds so rapidly that the transverse-cleavage follows immediately on the length-cleavage, and the two are at length made to coincide, two-fold division is changed into four-fold division. And when the process is repeated in quick succession, and the body falls at last into a number of small and equal pieces, we have manifold division (polytomy); as in the spore-formation of the sporozoa and rhizopoda, and in the embryonic sac of the phanerogams.

Asexual propagation by budding is chiefly distinguished from segmentation by the fact that the determining transgressive growth is only partial in the one and total in the other. The bud produced is, therefore, younger and smaller than the parent from which it issues; the latter may replace the lost part by regeneration and produce a number of buds simultaneously or successively without losing its individuality (whereas this is destroyed in division). Propagation by budding is rare among the protists, and more common among the histona —that is, with most of the tissue-plants and the lower, stock-forming tissue-animals (cœlenteria and vermalia). Most stocks (cormi) are formed by a sprout or person shooting out buds which remain united to it. The layer and shoots of tissue-plants are detached buds. The two chief kinds of gemmation are terminal and lateral. Terminal budding takes place at the end of the long-axis, and is not far removed from transverse division (for instance, the strobilation of the acraspedæ medusæ and the chain tape-worms). Lateral budding is much more common; it determines the branching of trees and generally of complex plants, and also of the tree-shaped stocks of sponges, cnidaria (polyps, corals), bryozoa, etc.

A third form of asexual reproduction is the formation of spores or "germ-cells," which are usually produced in great numbers inside the organism, then detached from it, and developed into new organisms without needing fertilisation. The spores are sometimes motionless (rest-spores or paulospores); sometimes they have one or more lashes which enable them to swim about (rambling-spores or planospores). This monogenetic propagation is very common among the protists, both protophyta and protozoa. Among the latter the sporozoa (gregarinæ, coccidia, etc.) are remarkable for the passing away of the whole unicellular organism in the formation of spores; in this case and in many of the rhizopods *(mycetozoa)* the process coincides with manifold cell-division. In other cases (radiolaria, thalamophora) only a portion of the parental cells is used for the production of spores. Spore-formation is very common among the cryptogams; here it usually alternates with sexual propagation. The spores are generally formed in special spore-capsules (sporangia). In the flowering plants (anthophyta) sporogony has disappeared. It is found at times in the tissue-animals (in the fresh-water sponges); in this case the sporangia are called *gemmulæ*.

The essential feature of sexual generation is the coalescence of two different cells, a female ovum (egg-cell) and a male sperm-cell. The simple new cell which arises from the blending of these is the stem-cell *(cytula)*, the stem-mother of all the cells that make up the tissues of the histon. But even among the unicellular protists we find in many places the beginnings of sexual differentiation; it is foreshadowed in the blending or copulation of two homogeneous cells, the gameta. We may conceive this process, or zygosis, as a peculiar and very favourable

kind of growth, that is connected with a rejuvenescence of the plasm; the latter is enabled to propagate by repeated cleavage through the mixing of the two different plasma-bodies on either side *(amphimixis)*. When these two gameta become unequal and differ in size and shape, the larger female body is called the macrogameton or macrogonidion, and the smaller, male part, the microgameton or microgonidion. Among the histona the first is called the egg-cell *(ovulum)*, and the latter the sperm-cell *(spermium*, or *spermatozoon)*. As a rule the latter is a very mobile ciliated cell, the former an inert or amœboid cell. The vibratory movements of the sperm-cells serve for approaching the ovulum in order to fertilise it.

The qualitative difference between the two copulating sexual cells *(gonocyta)*, or the chemical difference between the ovoplasm of the female and the sperm-plasm of the male cell, is the first (and often the only) condition of amphigony; subsequently we find in addition (in the higher histona) a very elaborate apparatus of secondary structures. With this chemical difference is associated a peculiar double form of sensitive perception and an attraction based thereon, which is called sexual chemotaxis or erotic chemotropism. This "sex-sense" of the two gonocyta, or elective affinity of the male andropIasm and the female gynoplasm, is the cause of mutual attraction and union. It is very probable that this sexual sense-function, akin to smell or taste, and the movements it stimulates, are located in the cytoplasm of the two sex-cells, while heredity is the function of the caryoplasm of the nucleus. (*Cf.* the *Anthropogeny*, chaps. vi. and vii.)

The sexual difference between the two forms of gono-plasm, the ovoplasm of the female and spermoplasm of the male cell, is noticeable at the very beginning of sexual differentiation in the different sizes of the

copulating gameta, and later in their increasing divergence as to shape, composition, movement, etc. It leads further to the distribution of the germinal regions (in which the sex-cells are formed) into two different individuals. When the ovum and the sperm-cell are produced in one and the same individual, we call this an hermaphrodite; and when they are formed in two different individuals (male and female), we call them monosexual, or gonochorists. In accordance with the various stages of individuality which we distinguished above (chap. vii.), we may indicate the following stages of hermaphrodism and gonochorism.

Some groups of protists, especially the highly-organised ciliated infusoria *(ciliata)*, are distinguished by having a separation of male and female plasm within the unicellular organism. The ciliata propagate, as a rule, in large numbers by repeated division (by indirect cell-cleavage). But this monogony has its limits, and has to be interrupted from time to time by amphigony, a rejuvenation of tbe plasm, which is effected by the conjugation of two different cells and the partial destruction of their nuclear matter. By conjugation is meant the partial and momentary union of two different unicellulars, while copulation is a total and permanent coalescence. When two ciliated infusoria conjugate they place themselves side by side, and connect for a time by means of a bridge of plasm. A part of the nucleus of each has already divided into two portions, one of which functions as the female standing-nucleus *(paulocaryon)* and the other as the male travelling-nucleus *(planocaryon)*. The two mobile nuclei enter the plasm-bridge, and move through it, pushing against each other, into the body of the opposite cell; they then coalesce with the deeper-lying standing-nucleus. When a fresh nucleus has been

thus formed (by *amphimixis*) in each of the copulating cells, they again separate. The two rejuvenated cells have once more acquired the power to propagate for a long time by division.

This peculiar hermaphroditic formation of the cells, which distinguishes the ciliated infusoria and some other protists, and which we now know in its smallest details through the investigations of Richard Hertwig, Maupas, and others, is especially interesting because it proves that the chemical difference between the female gynoplasm and the male androplasm can be found within a single cell. This erotic division of labour is so important that formerly it was universally ascribed to two different cells. Recent accurate research, penetrating into the smallest visible processes of fertilisation, has shown that the essential feature in the formation of a fresh individual (the stem-cell) is the blending of equal portions (hereditary parts) of the male and female nuclei; the caryoplasm of the two copulating cells is the vehicle of heredity from the parents. The cytoplasm of the cell-body, on the other hand, serves the purposes of adaptation and nutrition. As a rule the cell-body of the ovulum is very large, and is, as a food-store, very richly provided with albumin, fat, and other nutritive matter (food-yelk); while the cytoplasm of the sperm-cell is very small, and generally forms a vibrating lash, with which it moves along and seeks the ovum.

In most of the plants the female and male cells are produced by the same sprout, and in many of the lower animals by one and the same person. This kind of hermaphrodism in "individuals of the second order" is called monoclinism ("one-beddedness"). In many of the higher plants (monœcic stocks) and most of the higher animals we have diclinism ("two-beddedness")—in other

words, the one sprout or person has only male, and the other sprout or person only female, organs—this is gonochorism of individuals of the second order. Monoclinism is generally associated with sedentary life (and often necessary for it), and diclinism with free movement. Adaptation to parasitic habits also favours monoclinism; thus, the crabs, for instance, are for the most part gonochoristic individuals, but the creeping crabs *(cirripedia)*, which have adopted sedentary (and to an extent parasitic) habits, have become hermaphrodites in consequence. Many intestinal parasites among the lower animals (such as tape-worms, suctorial worms, wonder-snails), which live isolated lives inside other animals, have to be hermaphroditic and able to fertilise themselves if the species is to be maintained. On the other hand, many hermaphroditic flowers, although they have both sorts of sex-organs, are incapable of fertilising themselves, and have to receive this from insect visitors which carry the pollen from one flower to another.

Individuals of the third order, which we call stocks *(cormi)* in both the plant and animal worlds, also exhibit varying features in the sex-persons which compose them. When male and female diclinic sprouts or persons are found side by side on the same stock, we call this hermaphrodism of the cormi *monœcia* ("one-housedness"); this is the case with most of the siphonophora and some of the corals. *Diœcia* ("two-housedness") is less common: in this one stock has only male and the other only female sprouts or persons, as in poplars and osiers, most of the corals, and some of the siphonophora. The physiological advantages of crossing—the union of sex-cells of different individuals—favour progressive sex-division in the higher organisms.

A comparative study of the features of hermaphrodism

and sex-division in the plant and animal worlds teaches us that both forms of sex-activity are often found in closely related organisms of one and the same group, sometimes even in different individuals of the same species. Thus, for instance, the oyster is usually gonochoristic, but sometimes hermaphroditic; and so with many other molluscs, vermalia, and articulata. Hence, the question often raised, which of the two forms of sex-division is original, is hardly susceptible of a general answer, or without relation to the stage of individuality and the place in classification of the group under discussion. It is certain that in many cases hermaphrodism represents the original feature; for instance, in most of the lower plants and many of the stationary animals (sponges, polyps, platodes, tunicates, etc.). Where we find exceptions in these groups, they are of secondary origin. It is equally certain, on the other hand, that in other cases the separation of the sexes is the primitive arrangement; as in siphonophoræ, ctenophoræ, bryozoa, cirripedia, and molluscs. In these cases the hermaphrodism is clearly secondary in the sense that the hermaphrodites descend originally from gonochorists.

It is only in a few sections of the lowest histona that the two kinds of sex-cells arise without a definite location in different parts of the simple tissue, as in a few groups of the lower algæ and in the sponges. As a rule they are formed only at definite positions and in a special layer of the tissue-body, and mostly in groups, in the shape of sexual glands *(gonades)*. These bear special names in different groups of the histona. The female glands are called archegonia in the crytogams, *nucellus* (formed from the macrosporangia of the pteridophyta) in the phanerogams, and ovaries in the metazoa. The

male glands are called antheridia in the crytogams, pollen-sacs (formed from the microsporangia of the ferns) in the phanerogams, and testicles (as *spermaria*) in the metazoa. In many cases, especially in aquatic lower animals, the ovula (as products of the ovaries) are discharged directly outwards. But, in most of the higher organisms, special sexual ducts *(gonoductus)* have been formed to conduct both kinds of the gonocyta out of the organism.

While the two kinds of sexual glands are usually located in different parts of the generating organism, there are, nevertheless, a few cases in which the sex-cells are formed directly and together from one and the same gland. These glands are called hermaphroditic glands. Such structures are very notable in several highly differentiated groups of the metazoa, and have clearly been developed from gonochoristic structures in lower forms. The class of crested medusæ, or ribbed medusæ (ctenophoræ), contains glass-like, sea-dwelling cnidaria of a peculiar and complicated build, which probably descend from hydromedusæ (or craspedota). But whereas the latter have very simple gonochoristic structures (four or eight monosexual glands in the course of the radial canals or in the gastric wall), in the ctenophoræ the eight hermaphroditic canals run in a meridian arch from one pole of the cucumber-shaped body to the other. Each canal corresponds to a ciliary streamer, and forms ovaries at one border and testicles at the other; and these are so arranged that the eight intercostal fields (the spaces between the eight streamers) are alternately male and female. Still more curious are the hermaphroditic glands of the highly-organised, land-dwelling, and air-breathing lung-snails *(pulmonata)*, to which our common garden snail *(arion)* and vineyard snail

[illegible] mother's [illegible] in the [illegible] organisms, and the [illegible] opening of these [illegible] are developed,

[illegible] directly encounter [illegible] organisms), special [illegible] to convey the fertilising [illegible] female body. This process of copulation becomes important, as it is associated with characteristic feelings of pleasure, which may cause extreme psychic excitement; as sexual love it becomes, in man and the higher animals, one of the most powerful springs of vital activity. In many of the higher [illegible] vertebrates, articulates, and molluscs) [illegible] a number of glands and other [illegible] co-operate in the copulation.

[illegible] relations which exist, in [illegible] (especially vertebrates and [illegible] sexual life and their higher

psychic activity, have given rise to plenty of "wonders of life." Wilhelm Bölsche has so ably described them in his famous and popular work, *The Life of Love in Nature*, that I need only refer the reader to it. I will only mention the great significance of what are called "secondary sexual characters." These characteristics of one sex that are wanting in the other, and that are not directly connected with the sexual organs—such as the man's beard, the woman's breasts, the lion's mane, or the goat's horns—have also an æsthetic interest; they have, as Darwin showed, been acquired by sexual selection, as weapons of the male in the struggle for the female, and *vice versâ*. The feeling of beauty plays a great part in this, especially in birds and insects; the beautiful colours and forms which we admire in the male bird of paradise, the humming-bird, the pheasant, the butterfly, etc., have been formed by sexual selection *(cf.* the *History of Creation)*.

In various groups of the histona the male sex has become superfluous in the course of time; the ovula develop without the need of fertilisation. That is particularly the case in many of the platodes (trematodes) and culates (crustacea and insects). In the bees we kable feature that it is only decided at m it of laying the egg whether it is to be ; in the one event a female and in the ə bee is formed from it. When Siebold ı these facts of miraculous conception ı ɜ, he visited by the Catholic t city, ıo expressed his gratification tific explanation possible of ə Virgin Mary. Siebold had, point out to him that the inference s of the articulate to that of the

vertebrate was not valid, and that all mammals, like all other vertebrates, reproduce exclusively from impregnated ova. We also find parthenogenesis among the metaphyta, as in the *chara crinita* among the algæ, the *antennaria alpina* and the *alchemilla vulgaris* among the flowering plants. We are, as yet, ignorant for the most part of the causes of this lapse of fertilisation. Some light has been thrown on it, however, by recent chemical experiments (the effect of sugar and other water-absorbing solutions), in which we have succeeded in parthenogenetically developing unfertilised ova.

In the higher animals the complete maturity and development of the specific form are requisite for reproduction, but in many of the lower animals it has been observed recently that ovula and sperm-cells are even formed by the younger specimens in the larva stage. If impregnation takes place under these conditions, larvæ of the same form are born. And when these larvæ have afterwards reached maturity and reproduced in this form, we call the process *dissogony* ("double-generation"). It is found in many of the cnidaria, especially the medusæ. But if larvæ propagate by unfertilised ova, and so reproduce their kind parthenogenetically, the process is known as *pædogenesis* ("young-generation"). It is found particularly in the platodes (trematodes) and some of the insects (larvæ of *cecidomyca* and other flies).

In a large number of lower animals and plants sexual and asexual generation regularly alternate. Among the protists we find this alternation of generation in the sporozoa; among the metaphyta in the mosses and ferns; and among the metazoa in the cnidaria, platodes, tunicates, etc. Often the two generations differ considerably in shape and degree of organisation. Thus, in the mosses the asexual generation is the spore-forming moss

capsule *(sporogonium)*, while the sexual is the moss plant with stalk and leaves *(culmus)*. In the case of the ferns, on the other hand, the latter is spore-forming and monogenetic, while the thallus-formed, simple, and small fore-germ *(prothallium)* is sexually differentiatiated. In most of the cnidaria a small stationary polyp is developed out of the ovum of the free-swimming medusa, and this polyp, in turn, generates by budding medusæ, which reach sexual maturity. In the tunicates (salpa) a sexual social form alternates with an asexual solitary form; the chain-salpa of the former are smaller and differently shaped than the large individual salpa of the latter, which again generate chains by budding. This special form of metagenesis was the first to be observed, as it was in 1819 by the poet Chamisso, when he sailed round the world. In other cases (for instance, in the closely-related *doliolum*) a sexual generation alternates with two (or more) neutral ones. The explanation of these various forms of alternating generations is given in the laws of latent heredity (atavism), division of labour, and metamorphosis, and especially by the biogenetic law.

While in real metagenesis (alternation of generations in the strict sense) the asexual generation propagates by budding or spore-formation, this is done partheno-genetically in the cognate process of heterogenesis. This it is which, especially in many of the articulates, causes an immense increase of the species in a short time. Among the insects we have the leaf lice (aphides), and among the crustacea the water fleas (daphnides), that propagate in great numbers during warm weather by unfertilised "summer-ova." It is not until the autumn that males appear and fertilise the large "winter-ova"; in the following spring the first

parthenogenetic generation issues from the winter eggs. The two heterogenetic generations are very different in the parasitic suctorial worms (trematodes). From the fertilised ovum of the hermaphrodite distoma we get simply constructed nurses (pædogenetic larvæ), inside which cercaria are generated from unfertilised ova; these travel, and are afterwards converted (inside another animal) into distoma once more.

I have given (*General Morphology*, ii., 104) the name of strophogenesis to the complicated process of cell-reproduction, which we find in the ontogeny of most of the higher histona, both phanerogams and cœlomaria. In these there is not a real alternation of generations, as the multicellular tissue-forming organism developes directly from the impregnated ovum. But the process resembles metagenesis in so far as the ontogenetic construction consists itself in a repeated division of the cells. Many generations of cells proceed by cleavage from the one stem-cell (the impregnated ovum) before two of these cells become sexually differentiated, and form a generation of sexual cells. However, the essential difference consists in the fact that all these generations of cells—in the body of both the higher animals and the flowering plants—remain joined together as parts of a single bion (a unified physiological individual); but in the alternation of generations each group produced is made up of a number of bionta, which live as independent forms—often so different from each other that they were formerly thought to be animals of separate classes, such as the polyps and medusæ. Hence we must not describe the reproductive circle of the phanerogams as an alternation of generations, although it has started from the fern (by abbreviated heredity).

All simple forms of sexual reproduction without alternation of generations are comprised under the title of

*hypogenesis*. The generative cycle proceeds from ovum to ovum in one and the same bion or physiological individual. This form of development is usual with most of the higher animals and plants; it may proceed with or without metamorphosis. The younger forms which arise temporarily in the latter case, and are distinguished from the sexually-ripe form by the possession of the provisional (and subsequently disappearing) organs —larva organs (for instance, the tadpole or the pupa), are comprised under the general head of larvæ.

As a rule, only organisms of the same species seem to have sexual union and generate fertile progeny. This was formerly a rigid dogma, and served the purpose of defining the loose idea of the species. It was said: "When two animals or plants can have fertile offspring they belong to the same real species." This principle, which once afforded support to the dogma of the constancy of species, has long been discarded. We now know by numbers of sound experiments that not only two closely related species, but even two species of different genera, may have sexual intercourse in certain circumstances, and that the hybrids thus generated can have fertile offspring, either by union among themselves or with one of the parents. However, the disposition to hybridism varies considerably, and depends on the unknown laws of sexual affinity. This sexual affinity must be based on the chemical properties of the plasm of the copulating cells, but it seems to show a good deal of vagueness in its effect. As a rule, hybrids exhibit a combination of the features of both parents.

It has been proved by many recent experiments that hybrids have a more powerful build and can reproduce more strongly than pure offspring, whereas pure selection has generally in time an injurious effect. A

freshening by the introduction of new blood seems to be good from time to time. Hence, it is just the reverse of what the former dogma of the constancy of species affirmed. The question of hybridism has, generally speaking, no value in defining the species. Probably many so-called "true species," which have relatively constant features, are really only permanent hybrids. This applies especially to lower sea-dwelling animals, the sexual products of which are poured into the water and swarm together in millions. As we know of various species of fishes, crabs, sea-urchins, and vermalia, that their hybrids are very easily produced and maintained by artificial impregnation, there is nothing to prevent us from believing that such hybrids are also maintained in the natural state.

The short survey we have made of the manifold varieties of reproduction is sufficient to give an idea of the extraordinary wealth of this world of wonders. When we go more closely into details we find hundreds of other remarkable variations of the process on which the maintenance of the species depends. But the most important point of all is the fact that all the different forms of tocogony may be regarded as connected links of a chain. The steps of this long ladder extend uninterruptedly from the simple cell-division of the protists to the monogony of the histona, and from this to the complicated amphigony of the higher organisms. In the simplest case, the cell-cleavage of the monera, propagation (by simple transverse division) is clearly nothing more than transgressive growth. But even the preliminary stage of sexual differentiation, the copulation of two equal cells *(gameta)*, is really nothing but a special form of growth. Then, when the two gameta become unequal in the division of labour, when the larger

inert macrogameton stores up food in itself, and the smaller, mobile microgameton swims in search of it, we have already expressed the difference between the female ovum and the male sperm-cell. And in this we have the most essential feature of sexual reproduction.

The reproduction of the organism is often regarded as a perfect mystery of life, and as the vital function which most strikingly separates the living from the lifeless. The error of this dualistic notion is clear the moment one impartially considers the whole gradation of forms of reproduction, from the simplest cell-division to the most elaborate form of sexual generation, in phylogenetic connection. It is obvious all through that transgressive growth is the starting point in the formation of new individuals. But the same must be said of the multiplication of inorganic bodies—the cosmic bodies on the larger scale, crystals on the smaller scale. When a rotating sun passes a certain limit of growth by the constant accession of falling meteorites, nebulous rings are detached at its equator by centrifugal force, and form into new planets. Every inorganic crystal, too, has a certain limit of individual growth (determined by its chemical and molecular constitution). However much mother-water you add, this is never passed, but new crystals (daughter-crystals) form on the mother-crystal. In other words, growing crystals propagate.

## Chapter XII.

# MOVEMENT

**Mechanics as the science of motion (kinematics and phoronomism). Chemistry of vital movement. Active and passive movements. Undulatory movement. Mechanism of imbibition. Autonomous and reflex movements. Will and willing. Mixed movements. Movements of growth. Direction of the vital movement. Direction of the crystallising force. Direction of cosmic motion. Movements of protists. Amœboid, myophenous, hydrostatic, secretory, vibratory movements: cilia and lashes. Movements of histona, metaphyta and metazoa. Locomotion of tissue animals: ciliary motion and muscular movements. Muscles of the skin. Active and passive organs of movement. Radiata, articulata, vertebrata, mammalia. Human movements.**

All things in the world are in perpetual motion. The universe is a *perpetuum mobile*. There is no real rest anywhere; it is always only apparent or relative. Heat itself, which constantly changes, is merely motion. In the eternal play of cosmic bodies countless suns and planets rush hither and thither in infinite space. In every chemical composition and decomposition the atoms, or smallest particles of matter, are in motion, and so are the molecules they compose. The incessant metabolism of the living substance is associated with a constant movement of its particles, with the building-up and decay of plasma-molecules. But here we must disregard all these elementary kinds of movement, and be content with a brief consideration of those forms of motion which are peculiar to organic life, and a comparison of them with the corresponding motions of inorganic bodies.

The science of motion, or mechanics, is now taken in very different senses: (1) in the widest sense as a philosophy of life [generally called mechanism or mechanicism in England], equivalent to either monism or materialism; (2) in the stricter sense as the physical science of motion, or of the laws of equilibrium and movement in the whole of nature (organic and inorganic); (3) in the narrowest sense as part of physics, or dynamics, the science of moving forces (in opposition to statics, the science of equilibrium); (4) in the purely mathematical sense as a part of geometry, for the mathematical definition of magnitudes of movement; and (5) in the biological sense as phoronomy, the science of the movements of organisms in space. However, these definitions are not yet universally adopted, and there is a good deal of confusion. It would be best to follow the lead of Johannes Müller, as we are going to do here, and restrict the name phoronomy to the science of the vital movements which are peculiar to organisms, in contrast to kinematics, the exact science of the inorganic movements of all bodies. The real material object of phoronomy is the plasm, the living matter that forms the material substratum of all active vital movements.

On our monistic principles the inner nature of organic life consists in a chemical process, and this is determined by continuous movements of the plasma-molecules and their constituent atoms. As we have already considered this metabolism in the tenth chapter, we need do no more here than point out that both the general phenomena of molecular plasma-movement and their special direction in the various species of plants and animals can be reduced in principle to chemical laws, and are subject to the same laws of mechanics as all chemical

processes in organic and inorganic bodies. In this we emphasise our opposition to vitalism, which sees in the *direction* of plasma-movement the supernatural influence of a mystical vital force or of some ghostly "dominant" (Reinke). We agree with Ostwald, who also reduces these complex movements to the play of energy in the plasm—that is to say, in the last instance to modifications of chemical energy. In regard to the visible movements of the living things which concern us at present, we must first distinguish passive and active, and subdivide the latter into reflex and autonomous.

Many movements of the living organism which the inexpert are inclined to attribute to life itself are purely passive; they are due either to external causes which do not proceed from the living plasm, or to the physical composition of the organic but no longer living substance. Purely passive movements, which play an important part in bionomy and chorology, comprise such as the flow of water and the rush of the wind; they cause considerable changes of locality and "passive" migrations of animals and plants. Purely physical, again, is what is known as the Brownian molecular movement which we observe with a powerful microscope in the plasm of both dead and living cells. When very fine granules (for instance, of ground charcoal) are equally distributed in a liquid of a certain consistency, they are found to be in a constant shaking or dancing movement. This movement of the solid particles is passive, and is due to the shocks of the invisible molecules of the fluid which are continually impinging upon each other. In the rhizopods—the remarkable protozoa whose unicellular organism sheds so much light on the obscure wonders of life—we notice a curious streaming of the granules in the living plasm. Within the cytoplasm of the amœbæ particles travel up

and down in all directions. On the long thin plasma-threads or pseudopodia which stream out from the unicellular body of the radiolaria and thalamophora, thousands of fine particles move about, like promenaders in a street. This movement does not come from the passive granules, but from the active invisible molecules of the plasm, which are always changing their relative positions. Thus also the movements of the blood-cells which we can see with the microscope in the circulation of a young transparent fish, or in the tail of a frog-larva, are not due to the action of the blood-cells themselves, but to the flow of the blood caused by the beat of the heart.

An important factor in the life of many organisms, especially the higher plants, is the physical phenomenon called *imbibition;* it consists in the penetration of water between the molecules of solid bodies (drawn to them by molecular attraction), and the consequent displacement of the molecules by the fluid. In this way the volume of the solid body is increased, and movements are produced which may have the appearance of vital processes. The energy of these imbibitional bodies is notoriously very powerful; we can, for instance, split large blocks of stone by the insertion of a piece of wood dipped in water. As the cellulose membrane of plant-cells has this property of imbibition in a high degree (either in the living or the dead cell), the movements it causes are of great physiological importance. This is especially the case when the imbibition of the cell wall is one-sided, and causes a bending of the cell. In consequence of the unequal strain in the drying of many fruits, they split open and project their seeds to some distance (as do the poppy, snap-dragon, etc.). The moss-capsules also empty their spores as a result of imbibition-curving (in the teeth of the openings of the spore-cases). The

hygroscopic points of the heron-bill (*erodium*) curl up in the dry state and stretch out when moist; hence they are used as hygrometers in the construction of meteorological huts. The so-called "resurrection plants" (*anastatica*, the rose of Jericho, and *selaginella lepidophylla*), which close up like a fist when dry, spread their leaves out flat when moistened (the leaves imbibing strongly on the inner side). There is no more real case of "resuscitation" (as many believe) in these cases than in the mythological resurrection of the body. However, these phenomena of imbibition are not active vital processes; they are independent of the living plasm, and due solely to the physical constitution of the dead cell-membranes.

In contrast with these passive movements of organisms, we have the active movements which proceed from the living plasm. In the ultimate analysis, it is true, these may be reduced to the action of physical laws just as well as the passive movements. But the causes of them are not so clear and obvious; they are connected with the complicated chemical molecular processes of the living plasm, of the physical regularity of which we are now fully convinced, though their complicated mechanism is not yet understood. We may divide into two groups the many different movements, which are called vital in this stricter sense, and were formally regarded as evidences of the presence of a mystic vital force, according as the stimulus—the sensation of which is caused by the movement—is directly perceptible or not. In the first case, we have stimulated (or reflex or paratonic) movements, and in the second voluntary (autonomous or spontaneous) movements. As the will appears to be free in the latter, they have been left out of consideration by many physiologists, and handed over

to the treatment of the metaphysical psychologist. On our monistic principles this is a grave error; nor is it improved when "psychonomism" appeals to a false theory of knowledge. On the contrary, the conscious will (and conscious sensation) is itself a physical and chemical process like unconscious and involuntary movement (and unconscious feeling). They are both equally subject to the law of substance. However, only the external stimuli which cause reflex movements are known to us to any great extent and experimentally recognisable; the internal stimuli, which affect the will, are mostly unknown, and are not directly accessible to investigation. They are determined by the complicated structure of the psychoplasm, which has been gradually acquired by phylogenetic processes in the course of millions of years.

The great problem of the will and its freedom—the seventh and last of Dubois-Reymond's world-riddles—has been dealt with fully in the *Riddle* (chap. vii.). But as we still meet with the most glaring contradictions and confusion in regard to this difficult psychological question, I must touch upon it briefly once more. In the first place, I would remind the reader that it is best to restrict the name "will" to the purposive and conscious movements in the central nervous system of man and the higher animals, and to give the name of impulses (tropisms) to the corresponding unconscious processes in the psychoplasm of the lower animals, as well as of the plants and protists. For it is only the complicated mechanism of the advanced brain structure in the higher animals, in conjunction with the differentiated sense-organs on the one side and the muscles on the other, that accomplishes the purposive and deliberate actions which we are accustomed to call acts of will.

But the distinction between voluntary (autonomous) and involuntary (reflex) movements is as difficult to carry out in practice as it is clear in theory. We can easily see that the two forms of movement pass into each other without any sharp boundary (like conscious and unconscious sensation). The same action, which seems at first a conscious act of the will (for instance, in walking, speaking, etc.), may be repeated the next moment as an unconscious reflex action. Again, there are many important mixed or instinctive movements, the impulse to which comes partly from internal and partly from external stimuli. To this class belong especially the movements of growth.

Every natural body that grows increases its extent, fills a larger part of space, and so causes certain movements of its particles; this is equally true of inorganic crystals and the living organism. But there are important differences between the growth in the two cases. In the first place, crystals grow by the external apposition of fresh matter, while cells grow by the intussusception of fresh particles within the plasm (*cf.* chap. x.). In the second case, in growth, which determines the whole shape of the organism, two important factors always co-operate, the inner stimulus, which depends on the specific chemical constitution of the species, and is transmitted by heredity, and the external stimulus which is due to the direct action of light, heat, gravity, and other physical conditions of the environment, and is determined by adaptation (phototaxis, thermotaxis, geotropism, etc.).

A peculiar property of many vital movements (but by no means all) is the definite direction they exhibit; these are generally called purposive movements. For the teleologist they afford one of the chief and most

welcome proofs of the dualistic theory of the older and the modern vitalism. Baer, especially, has laid stress on the purposiveness of all vital movement. It has been given a more precise expression recently by Reinke. His "dominants" are "intelligent directive forces," essentially different from all forms of energy or natural forces, and not subject to the law of substance. These metaphysical "vital spirits" are much the same as the immortal soul of dualistic psychology or the divine emanations of ancient theosophy. They are supposed, not only to regulate the special development and construction of every species of animal and plant, and direct it to a pre-determined end, but also to control all the various movements of the organism and its organs down to the cells. These "hyperenergetic forces" are equivalent to the "organising principle" and the "unconscious will" of Edward Hartmann, the "arranging and controlling protoplasmic forces" of Hanstein and others. All these metaphysical, supernatural, and teleological ideas, like the older mystic notion of a special vital force, rest on a perversion of judgment by the apparent freedom of will and purposiveness of organisation in the higher organisms. These thinkers overlook the fact that this purposiveness can be traced phylogenetically to simple physical movements in the lower organisms. Moreover, they overlook or deny the definite direction of inorganic forms of energy, though this is just as clear in the origin of a crystal as in the composition of the whole world-structure, in the direction of the mind as in the orbit of a planet. Hence it is important to bear in mind always these two forms of mechanical energy, and emphasise their identity with the direction of vital movement.

The force of gravitation which is at work in

crystal-formation in the simple chemical body exhibits just as definite a direction as that which appears in the plasm in cell-construction. In this and other respects the comparison of the cell with the crystal, which was made even by the founders of the cell-theory, Schleiden and Schwann, in 1838, is thoroughly justified, though it is not correct in some other aspects. When the crystal is formed in the mother-water, the homogeneous particles of the chemical substance arrange themselves in a perfectly definite direction and order, so that mathematical planes of symmetry and axes arise within, and definite angles at the surface. On the strength of this, modern crystallography distinguishes six different systems of crystals. But, in different conditions, the same substance may crystallise in two or even three different systems (dimorphism and trimorphism of the crystal); thus, for instance, carbonate of lime crystallises as calc-spar in the hexagonal, and as arragonite in the rhombic system. If Reinke would be consistent, he ought to postulate a " dominant " for every crystal, to control the order and direction of the particles in its formation. He makes the curious statement (in 1899) that direction " is not a measurable magnitude " like energy, and so is not subject, like it, to the law of substance. We can mathematically determine the direction of the constructive force in the crystal just as well as in the cell.

If we comprise under the head of cosmokinesis the whole of the movements of the heavenly bodies in space, we cannot deny that they have a definite direction in detail, although our knowledge of this is still very incomplete. We can calculate the distances and speeds and movements of the planets round the sun with mathematical accuracy; and we gather from our astronomical observations and calculations that a similar

regularity prevails in the movements of the other countless bodies in infinite space. But we do not know either the first impulse to these complex movements or their final goal. We can only conclude from the great discoveries of modern physics, supported by spectrum analysis and celestial photography, that the universal law of substance on the one side and the law of evolution on the other control the gigantic movements of the heavenly bodies just as they do the living swarm of tiny organisms that have inhabited our little planet for millions of years. Reinke ought, consistently, to admire the cosmic intelligence of the Supreme Being in these movements of the cosmic masses and its emanations, the "dominants," in the actual direction of their movements, as much as he does in the plasma-flow in the tiny organism.

The manifold gradation of vital movement which we find everywhere in the higher organisms is not without expression even in the protist realm. In this respect the chromacea, the simplest forms of vegetal monera, and the bacteria, which we regard as corresponding animal forms, developed from the former by metasitism, are of great interest. As microscopic scrutiny fails to detect any purposive organisation in these unnucleated cells, and it is impossible to discover different organs in their homogeneous plasma-body, we have to look upon their movements as direct effects of their chemical molecular structure. But the same must be said also of a number of nucleated cells, both among the protophyta and the protozoa; only in this case the structure is less simple, in so far as both the nucleus itself and the surrounding cell-body exhibit, in indirect division, complicated movements in the plasm (caryokinesis). Apart from these, however, there is nothing to be seen in many

unicellular beings (*e.g.*, paulotomea, or calcocytea) that we need call "vital movement." On the border between the organic and inorganic worlds we have, as regards movement, the simplest forms of the chromacea, chroococcacea. We can see no vital movement in these structureless particles of plasm except slight changes of form, which occur when they multiply by cleavage. The internal molecular movements of the living matter, which effect their simple plasmodomous metabolism and growth, lie beyond our vision. The reproduction itself, in its simplest form of self-cleavage, seems to be merely a redundant growth, exceeding the limit of individual size for the homogeneous plasma-globule (*cf.* chaps. ix. and x.).

The great majority of the protists have the appearance of real, nucleated cells. Hence we have to distinguish two different forms of movement in the unicellular organism—the inner movement in the caryoplasm of the nucleus and the outer in the cytoplasm of the cell-body; the two enter into close mutual relations during the remarkable process of partial resolution of the nucleus (caryolysis). In this modification and partial dissolution of their constituents we observe, during indirect cell-division, certain complicated movements (the significance of which is as yet entirely unknown), that are accomplished by both the granules of chromatin and the threads of achromin, and which are comprised under the head of nuclear movements (caryokinesis). It has lately been attempted to explain them on purely physical principles. The same may be said of the internal flow of the plasm which we find in the plasmodia of the amœbæ and mycetozoa, and in the endoplasm of many of the protophyta and protozoa.

The slow displacement of the molecules of plasm

which is at the bottom of these plasma-movements also causes a variety of external changes of form in simple naked cells. Variable processes like folds or fingers (the "fold-feet," *lobopodia*) appear on their surface. As they are best observed in the common amœbæ (naked nucleated cells of the simplest kind), they are called amœboid movements. With these is connected the variable movement of the larger rhizopods, the radiolaria and thalamophora, in which hundreds of fine threads radiate from the surface of the naked plasma-body. A number of recent experts on the rhizopods, such as Bütschli, Richard Hertwig, Rhumbler, and others, have attempted to trace to purely physical causes this varying formation of pseudopodia, and their branching and net-like structure (without definite direction).

It is more difficult to do this in the case of the most highly differentiated of the protozoa, the infusoria. With these the free movement of the unicellular protozoon is farther advanced through the formation of permanent hair-like processes (long single lashes in the flagellata, and a number of short lashes in the ciliata) on the cell-surface and the movement of these by contraction and expansion, like the limbs, tentacles, and bones of the higher animals. The apparent spontaneity and various modulation in the ever-changing movements of these cell-feet is, in many of the infusoria, so like the antonomous voluntary movements in the metazoa that several experts on the infusoria have been moved on this account to ascribe individual (and even conscious) souls to them. Hence the difference between the various kinds of living movement is already very considerable before we leave the kingdom of the protists. On the one hand, the lowest monera (chromacea) join on directly to inorganic phenomena. On the other hand,

the highly differentiated infusoria (ciliata) show so great a resemblance to the higher animals in their differentiated and antonomous movements that they have been credited with the possession of "free-will." There is no such thing as a sharp division.

In a large section of the higher protozoa differentiated organs of movement are developed, which may be compared to the muscles of the metazoa. In the cytoplasm thread-like, contractile structures are formed, and these have, like the muscular fibres of the metazoa, the power to contract and expand again in definite directions. These myophæna or myonema form, in many of the infusoria, both ciliata and flagellata, a special thin layer of parallel or crossed fibres underneath the exoplasm or the hyaline skin-layer of the cell. The metabolic body of the infusorium may be altered in various ways by the autonomous contraction of these. Special instances of these myophæna are the *myophrisca* of the acantharia—contractile threads which surround the radial needles of these radiolaria like a crown. They are found in their outer gelatine envelope, the calymma, and by their contraction extend it, and so lessen the specific gravity.

Many of the aquatic protophyta and protozoa have the power of antonomous and independent locomotion, and this often has the appearance of being voluntary. Among the simplest fresh-water protozoa are the arcellina or thecolobosa *(difflugia, arcella)*, little rhizopods that are distinguished from the naked amœbæ by the possession of a firm envelope. They usually creep about in the slime at the bottom, but in certain circumstances rise to the surface of the water. As Wilhelm Engelmann has shown, they accomplish this hydrostatic movement by means of a small vesicle of carbonic acid, which expands

their unicellular body like an air-balloon; the specific weight of the cell-body, which is of itself heavier than water, is sufficiently lowered by this. The same method is followed by the pretty radiolaria which live floating (as plankton) at various depths of the sea. Their unicellular (originally globular) body is divided by a membrane into a firm inner central capsule and a soft outer gelatine covering. The latter, known as the calymma, is traversed by a number of water-vesicles or vacuoles. As a result of an osmotic process, carbonic acid may be secreted or pure water (without the salt of the sea-water) be imbibed in these vacuoles; by this means the specific gravity of the cell is lessened, and it rises to the surface. When it desires to make itself heavier and sink, the vacuoles discharge their lighter contents. These hydrostatic movements of the radiolaria (for which the myophrisca, still more complicated structures, have been developed in the acantharia) attain by simple means the same end that is accomplished in the siphonophora and fishes by air-filled and voluntarily contractile swimming-bladders.

Numbers of the unicellulars alter their position very characteristically by secreting a thick mucus at one side of their body and fastening this to the ground. If the secretion continues, a longish jelly-like stalk is produced by which the cell slowly pushes itself along, like a boat with a rowing-pole. This secretory locomotion is found, among the protophyta, in the desmidiacea and diatomes, and in some of the gregarinæ and rhizopods among the protozoa. The peculiar rolling movements of the oscillaria (thread-like chains of blueish-green unnucleated cells, closely related to the chromacea) are also effected by the secretion of mucus. On the other hand, it is probable that the sliding movements of many of the

diatomes are due to fine processes (vibratory hairs?) in the plasm, which proceed either out of the seams *(raphe)* of the bivalvular silicious shells or through the fine pores in them.

Especially important in the easy and rapid locomotion of many unicellulars is the formation of fine hair-like processes at the surface of the body; in the broadest sense, they are called vibratory hairs. If only a few whip-like threads are formed, they are called *whips (flagella)*; if many short ones, *lashes (cilia)*. Flagelliform movement is found in some of the bacteria, but especially in the mastigophorous "whip-infusoria," in the mastigota among the protophyta, and the flagellata among the protozoa. As a rule, we have in these cases one or two (rarely more) long and very thin whip-shaped processes, starting from one pole of the long axis of the oval, round, or long cell-body. These whips *(flagella)* are set in vibratory motion (apparently often voluntary) in various ways, and serve not only for swimming or creeping, but also for feeling and securing food. Similar whip-cells *(cellulæ flagellatæ)* are also found very commonly in the body of tissue-animals, usually packed together in an extensive layer at the inner or outer surface (ciliated epithelium). If single cells are released from the group, they may live independently for some time, continuing their movements and resembling free infusoria. The same may be said of the travelling spores of many of the algæ, and of the most remarkable of all ciliated cells—the spermia or spermatozoa of plants and animals.

As a rule, they are cone-shaped, having an oval or pear-shaped (though often also rod-shaped) head, which tapers into a long and thin thread. When their lively movements were first noticed in the male seminal fluid

(each drop of which contains millions of them) 200 years ago, they were thought to be real independent animalcules, like the infusoria, and so obtained their name of seed-animals (spermatozoa). It was a long time (sixty years ago) before we learned that they are detached glandular cells, which have the function of fertilising the ovum. It was discovered at the same time that similar vibratory cells are found in many of the plants (algæ, mosses, and ferns). Many of the latter (for instance, the spermatozoids of the cycadea) have, instead of a few long whips, a number of short lashes *(cilia)*, and resemble the more highly developed ciliated infusoria *(ciliata)*.

The ciliary movement of the infusoria is held to be a more perfect form of vibratory movement, because the many short lashes found on them are used for different purposes, and have accordingly assumed different forms in the division of labour. Some of the cilia are used for running or swimming, others for grasping or touching, and so on. In social combinations we have the ciliated cells of the ciliated epithelium of the higher animals—for instance, in the lungs, nostrils, and oviducts of vertebrates.

In the unicellular, non-tissue forming protists, all the vital movements seem to be active functions of the plasm of the single cell; but in the histona, the multicellular tissue-forming organisms, they are the outcome of the combined movements of the many cells which compose the tissue. Careful anatomic study and experimental physiological scrutiny of the motor processes are, therefore, first directed, in the case of the histona, to clearing up the nature and activity of the special cells which compose the tissue, and then the structure and functions of the tissue itself. When we start from this point, and survey the manifold active motor phenomena of the

histona as a whole, we see at once an essential agreement in the phoronomy of the two kingdoms of the metaphyta and metazoa, in the sense that at the lower stages the chemical and physical character of the motor processes can be clearly shown and can be traced to an interchange of energy in the plasm of the cells that make up the tissue. In the higher stages, however, we find striking differences, the voluntary character of many autonomous movements being very conspicuous in the higher animals, and thus the great problem of the freedom of the will is added to the purely physiological questions of stimulated movement, growth-movement, etc.

Moreover, the movements of the metazoa are much more varied and complicated than those of the metaphyta, in consequence of the higher differentiation of their sense-organs and the centralisation of their nervous system. The former have generally free locomotion and the latter not. The special mechanism of the organs of movement is also very different in the two groups. In most of the metazoa the chief motor organs are the muscles, which have developed in the highest degree the power of definitely directed contraction and expansion. In most of the metaphyta, on the other hand, the chief part of the movements depend on the strain of the living plasm, or what is called the *turgor* or expansibility of the plant-cells. This is effected by the osmotic pressure of the internal cell-fluid and the elasticity of the cellulose wall, which is thus expanded. Nevertheless, in both cases—and in all "vital" phenomena—the real cause of the process is, in the ultimate analysis, the chemical play of energy in the active plasm.

The metaphyta, with few exceptions, are fixed in one spot for life, or only mobile for a short time when they are young. In this they resemble the lower metazoa,

the sponges, polyps, corals, bryozoa, etc. They have not free locomotion. The motor phenomena which we find in them affect only special parts or organs. They are mostly reflex or paratonic, and due to external stimuli. Only a few of the higher plants exhibit autonomous or spontaneous movement, the stimulating cause of which is unknown to us, and which may be compared to the apparently voluntary actions of the higher animals. The lateral feather-leaves of an Indian butterfly flower *(hedysarum gyrans)* move in circles through the air, like a pair of arms swinging, without any external cause; they complete a circle in a couple of minutes. Variations in the intensity of light have no effect on them. Similar spontaneous movements of the leaves of several species of clover *(trifolium)* and sorrel *(oxalis)* are performed only in the dark, not in the light. The terminal leaf of the meadow clover repeats its rotation, which describes more than 120 degrees of an arc, every two to four hours. The mechanical cause of these spontaneous "variation movements" seems to lie in variations of expansibility.

Voluntary and autonomous turgescence-movements of this kind are only observed in a few of the higher plants, but stimulated movements that are accomplished by the same mechanism are very common in the vegetal world. We have, especially, the well-known "sleep," or nyktitropic movements, of many plants. Many leaves and flowers hold themselves vertically to the streaming rays of the sun. When darkness comes on they contract, and the calices of the flowers close. Many flowers are open for only a few hours a day. The mechanism of turgescence, which effects these swelling movements, consists in the co-operation of the osmotic pressure of the internal cell-fluid and the elasticity of the strained

cell-membrane enclosing the cytoplasm. The strain of the outer cellulose membrane on the plasmatic primordial sac within it grows so much on the accession of osmotically active matter that the internal pressure is equal to several atmospheres, and the elastic strained membrane stretches from ten to twenty per cent. When water is withdrawn again from one of these swollen or turgescent cells, the membrane contracts; the cell becomes smaller, and the tissue looser. Other stimuli besides light (heat, pressure, electricity) may produce these expansional variations, and, as a consequence of it, certain reflex movements (or paratonic variational movements). The most striking and familiar examples are the flesh-eating fly-trap *(dionœa muscipula)* and the sensitive plant *(mimosa pudica)*; their contraction is caused by mechanical stimuli, shaking, pressure, or the touching of the leaves.

Most of the higher animals have the power of free and voluntary locomotion. It is, however, wanting in some of the lower classes, which spend the greater part of their life at the bottom of the water, like plants. Hence these were formerly held to be vegetable—thus the sponges, polyps, and corals among the cœlenteria. A number of classes of the cœlomaria have also adopted the stationary life, such as the bryozoa and the spirobranchia among the vermalia, many mussels (oysters, etc.), the actinia among the tunicates, the sea-lilies *(crinoidea)* among the echinoderms, and even highly organised articulata, such as the tube-worms *(tubicolæ)*, among the annelids and the crawling crabs *(cirripedia)*, among the crustacea. All these stationary metazoa move freely in their youth, and swim about in the water as *gastrulæ*, or in some other larva form. They have taken only gradually to stationary habits, and have been

considerably modified, and often greatly degenerated, in consequence; for instance, in the loss of the higher sense-organs, the bones, and even of the whole head. Arnold Lang has shown this very clearly in his excellent work on the influence of stationary life on animals. The study of these retrogressive metamorphoses is very important for the theory of progressive heredity and selection; it also shows the great value of free locomotion for the higher sensitive and intellectual development of the animals and man.

In many of the lower aquatic metazoa the surface of the body is covered with vibratory epithelium—that is to say, with a layer of skin-cells which bear either one long whip *(flagellum)* or several short lashes (cilia). Flagellated epithelium is especially found in the cnidaria and platodes; ciliated epithelium mostly in the vermalia and mollusca. As the lashing motion of these hair-like processes brings a constant stream of fresh water to the surface of the body, they first of all effect respiration through the skin. But in many of the smaller metazoa they also serve the purpose of locomotion, as in the gastræads, the turbellaria, the rotifera, the nemertina, and the young larvæ of many other metazoa. The vibratory apparatus reaches its highest development in the *ctenophora*. The extremely delicate and soft body of these gherkin-shaped cnidaria swims slowly in the water by means of the strokes of thousands of tiny oar-blades. They are arranged in eight longitudinal rows which stretch from the mouth to the opposite pole. Each oar-blade consists of the long hair-lashes of a group of epithelial cells glued together.

The chief motor organs in the metazoa are the muscles which constitute the "flesh" of the body. Muscular tissue consists of contractile cells—that is to say, of

cells with the sole property of contraction. When the muscular cell contracts, it becomes shorter and its diameter increases. This brings nearer together the two parts of the body to which its ends are attached. In the lower metazoa the muscle-cells have, as a rule, no particular structure; but in the higher animals the contractile plasm undergoes a peculiar differentiation, which has the appearance under the microscope of a transverse streaking of the long cells. On this ground a distinction is drawn between striated muscles and simple non-striated or smooth muscles. The more vigorous, rapid, and definite is the contraction of the muscle, the more marked is the streaky character, and the more pronounced the difference between the doubly refractive muscular particles from the simple refractive. The striated muscle is "the most perfect dynamo we know of" (Verworn). The normal heart of a man accomplishes every day, according to Zuntz, a work of about 20,000 kilogrammetres—in other words, an energy that would suffice to lift to a height of one metre a weight of 20,000 kilogrammes. In many flying insects (gnats, for instance) the flying muscles make 300–400 contractions a second.

In the lower and higher classes of the metazoa the muscle amounts to no more than a thin layer of flesh underneath the skin. This layer consists of muscular cells, which come originally from the ectoderm in the form of internal contractile processes of the skin-cells themselves, as in the polyps. In other cases the muscle-cells are developed from the connective-tissue cells of the mesoderm, the middle skin-layer, as in the ctenophora. This mesenchymic muscle is less common than epithelial muscle. In most of the askeletal vermalia the sub-dermal muscle divides into two layers—an outer deposit

of concentric muscles and an inner layer of longitudinal muscles; in the cylindrical worms (nematodes, sagittæ, etc.) the latter fall into four longitudinal bands, one pair of upper (dorsal) and a pair of lower (ventral) muscular bands. At those parts of the body which are especially used for locomotion the muscle is more strongly developed, as in the belly-side of the crawling worms and molluscs. This muscular surface developes into a kind of fleshy "foot" *(podium)*; it assumes a great variety of forms in the various classes of molluscs. In most of the snails which creep on the solid ground it grows into a muscular "flat-foot" *(gasteropoda)*; in the mussels which cut like a plough through the soft slime it forms a sharp "hatchet-foot" *(pelecypoda)*. The keel-snails *(heteropoda)* swim by means of a "keel-foot," which works like the screw of a ship; the floating-snails *(pteropoda)* swim unsteadily (like butterflies flying) by means of a pair of head-folds, which develop from the side of the anterior foot-section. In the highest molluscs, the cuttle-fishes *(cephalopoda)*, this fore-foot divides into four or five pairs of folds, which grow into long and very muscular "head-arms"; the numbers of strong suckers on the latter have also special muscles. In all these non-articulate molluscs and vermalia hard skeletons are either altogether wanting or (like the external shells of the molluscs) they have no functional relation to the motor muscles. It is otherwise in the higher animals, in which we find this relation to a solid jointed skeleton that becomes a passive motor apparatus.

The higher groups of the animal kingdom in which a characteristic solid skeleton is developed and forms an important starting-point for the muscles, as well as a support and protection for the whole body, are the three stems of the echinoderms, articulates, and vertebrates.

All three groups are very rich in forms, and far surpass all the other stems of the animal world in the perfection of their locomotive apparatus. However, the disposition and development of the skeleton as a passive support, and the correlation of the muscles to it as active pulling-organs, differ very much in the three classes, and are the chief factors in determining their characteristic types; they show clearly (even apart from other radical differences) that the three stems have arisen independently of each other from three different roots in the vermalia-stem. In the echinoderms the calcareous skeleton is formed from chalky deposits in the corium, in the articulates from chitine secretions of the epidermis, and in the vertebrates from cartilage of an internal chord-sheath (*cf. Anthropogeny*, chap. xxvi.).

The remarkable stem of the sea-dwelling echinoderms or "prickly skins" is distinguished from all the other animal groups by a number of striking peculiarities; prominent among these are the special formation of their active and passive motor organs and the curious form of their individual development. In this ontogenesis two totally different forms appear successively—the simple astrolarva and the elaborately organised and sexually-mature astrozoon. The small, free-swimming astrolarva has the general structural features of the rotatoria, and so shows, in accordance with the biogenetic law, that the original stem-form of the echinoderms (the amphoridea) belonged to this group of the vermalia. I have briefly explained these structures in the *History of Creation* (chap. xxii.), and more fully in my essay on the amphoridea and cystoidea (1896). The little astrolarva has no muscles, and no water-vessels or blood-vessels. It moves by means of vibratory lashes or bands, which are attached to special arm-like processes at the surface.

These arms are regularly developed to the right and left of the bilateral symmetrical larva (which as yet shows no trace of the five-rayed structure). By a very curious modification the small bilateral astrolarva is transformed into the totally different pentaradial astrozoon, the large sexually-mature echinoderm with a pronounced five-rayed structure. (See *Art-forms in Nature*, plates 10, 20, 30, 40, 60, 70, 80, 90, and 95.) It has a most elaborate organisation, with muscles and cuticular skeleton, blood-vessels and water-vessels, etc. A section of the astrozoa —the living crinoidea, or sea-lilies, and the extinct classes of blastoidea (sea-buds), cystoidea (sea-apples), and amphoridea (sea-urns)—grow in stationary fashion at the bottom of the sea. The other four extant classes creep about in the sea—the sea-gherkins (holothuria), the star-fish (asteridea and ophoidea), and the sea-urchins (echinidea). Their creeping motion is accomplished by two kinds of organs—water-feet and skin-muscles. The latter find their support and attachment in solid calcareous needles, which develop from chalky deposits in the corium. As these calcareous needles (which are particularly conspicuous in the sea-urchin) are set moveably in special protuberances of the calcareous plates of the cuticular skeleton, and moved by little muscular needles, the echinoderms walk on them as if they were stilts. Between these, however, a number of water-feet arise from inside—thin tubes like the fingers of a glove, which are filled with water by an internal conduit-system (the so-called ambulacral system) and become stiff. These very extensible ambulacral feet, often provided with a suctorial plate at the closed outer end, serve for creeping, sucking, touching, and grasping. As these distinctive motor organs of the echinoderms —both the ambulacral feet with their complicated

water-tubes and the moveable needles with their joints and muscles—are found in hundreds, often in thousands, on every individual five-rayed astrozoon, we might say that the echinoderms have the most advanced and complicated motor organs of all animals. Their historical development is perfectly understood from its earliest stages, since Richard Semon found, in his ingenious pentactæa-theory (1888), the correct phylogenetic meaning of the curious embryology of the echinoderms discovered in 1845 by Johannes Müller. I endeavoured in 1896 to establish it in detail, in relation to paleontological discoveries, in the essay I have mentioned.

The large stem of the articulata (the richest in forms of all the animal stems) comprises three chief classes—the annelids, crustacea, and tracheata. All three groups agree in the essential features of their organisation, especially in the external articulation or metamerism of the long bilateral body, and also in the repetition of the internal organs in each joint or segment. In each joint there is orginally a knot of the ventral nervous system (the ventral marrow), a chamber of the dorsal heart, a chitine-ring of the cutaneous skeleton, and a corresponding group of muscles.

Of the three great classes of the articulates the annelids are developed directly from the vermalia, of which both the nematoda and nemertinæ approach very closely to them. The two other and more highly organised classes, the crustacea and tracheata, are younger groups, independently evolved from two different stems of the annelids. The annelids, or "ringed-worms" (to which, *e.g.*, the rain-worms belong), have mostly a very homogeneous articulation; their segments or metamera repeat the same structure to a great extent, especially the subdermal muscles. In a transverse section we see in

every joint underneath the layer of concentric muscles a pair of dorsal and a pair of ventral muscles. Their epidermis has secreted a thin covering of chitine, in the tubular worms a leather-like or calcified tube. There are no bones in the oldest annelids; in the younger bristle-worms *(polychæta)* one or two pairs of short unjointed feet *(parapodia)* are found in every joint.

The other two chief classes of the articulates develop long and jointed feet of very varied forms, and at the same time assume different shapes of limbs in the division of labour. This heterogeneous articulation (heteronomy) is the more pronounced the higher the whole organisation. This is equally true of the aquatic, gill-breathing crustacea (crabs, etc.) and the tracheata (terrestrial animals breathing through a trachea, the myriopods, spiders, and insects). In the higher groups of both classes the number of limbs is usually not higher than 15–20; and they are distributed in three principal sections—head, breast, and posterior part of the body. The firm covering of chitine, which was delicate and thin in most of the annelids, is much thicker in most of the crustacea and tracheata, and often hardened by a calcareous deposit; it forms a solid ring of chitine in each segment, inside which the motor muscles are attached. The successive hard rings are connected by thin, mobile, intermediate rings, so that the whole body combines firmness, elasticity, and mobility in a high degree. The structure of the long jointed legs, which are fixed in pairs on each segment, is very similar. Hence the typical character of the motor organs of the crustacea lies in the circumstance that both in the body and the limbs the muscles are attached to the interior of hollow chitine tubes, and go in these from member to member.

The vertebrates are just the reverse in structure. In

their case a solid internal skeleton is formed in the longitudinal axis of the body, and the muscles are external to these supporting organs. The articulation or metamerism itself is not visible externally in the vertebrates; it is only seen in the muscular system when the non-articulated skin has been removed. Then, even in the lowest skull-less vertebrates, the acrania, the internal skeleton of which consists merely of a cylindrical, solid, and elastic axial rod *(chorda)*, we see on each side a row of muscular plates (50–80 in the amphioxus). In this case there are not pairs of limbs, and it is the same with the oldest craniate animals, the cyclostoma (myxinoida and petromyzonta). It is only with the third class of the vertebrates, the true fishes *(pisces)*, that two pairs of lateral limbs appear—the breast-fins and belly-fins. From these, in their terrestrial descendants, the oldest amphibia of the carboniferous period, the two pairs of jointed legs—fore-legs (carpomela) and hind-legs (tarsomela)—are derived. These four lateral five-toed legs have a very characteristic and complicated articulation, both in the internal bony skeleton and the muscular system that encloses this and is attached to it. From the amphibia, the earliest quadrupeds, this locomotive apparatus is transmitted by heredity to their descendants, the three higher classes of the vertebrates, reptiles, birds, and mammals. As I have dealt with these important structures fully in my *Anthropogeny* (chap. xxvi.), and given a number of illustrations of them, I must refer the reader to that work,[1] and will only make a few observations on the mammals.

[1] A translation of the latest edition of the *Anthropogenie*, with the full number of fresh illustrations (30 plates and 512 wood cuts), will be issued very shortly by the Rationalist Press Association, under the title of *The Evolution of Man*.—TRANS.

Both parts of the motor apparatus, the internal bony skeleton (the passive supporting apparatus) and the external muscular system (the active motor), exhibit a great variety of construction within the mammal-class, in consequence of adaptation to the most different habits and functions. We have only to compare the running carnivora and ungulata, the leaping kangaroos and jerboas, the burrowing moles and hyperdæi, the flying cheiroptera and bats, the fish-like swimming sirens and whales, and climbing lemures and apes. In all these and the remaining orders of the mammals the whole regular structure of the motor apparatus is strikingly adapted to the habits of life which have been formed by this adaptation itself. Nevertheless, we see that the essential character of the inner organisation which distinguishes the mammals as a class is not affected by this adaptation, but constantly maintained by heredity. These recognised facts of comparative anatomy and ontogeny, and the concordant results of paleontology, prove convincingly that all living and fossil mammals, from the lowest ungulates and marsupials to the ape and man, have descended from one common stem-form, a pro-mammal, that lived in the Triassic period; its earlier ancestors in the Permian period were reptiles, and, in the Carboniferous period, amphibia. Among the characters of the locomotive apparatus which are peculiar to mammals we have, on the one hand, the structure of the vertebral column and the skull, and, on the other hand, the formation of the muscles which are attached to these supporting organs. In the skull we particularly notice the formation of the lower jaw and the joint by which it is connected with the temporal bone. This joint is temporal, and so distinguished from the square joint of the other vertebrates. The latter is

found in the mammals in the tympanic cavity of the middle-ear, between the hammer (the modified joint of the lower jaw, *articulare*) and the anvil (the original *quadratum*). In harmony with this remarkable modification of the maxillary joint, the corresponding muscles have naturally also undergone a considerable transformation. A distinctive muscle that is only found in the mammals and regulates their respiration is the diaphragm, which completely divides the abdominal and thoracic cavities; the various muscles, from the blending of which it has been formed, still remain separate in the other vertebrates.

The many organs by means of which our human organism accomplishes its manifold movements are just the same as in the apes, and the mechanism of their action is in no way different. The same 200 bones, in the same order and composition, form our internal bony skeleton; the same 300 muscles effect our movements. The differences we find in the form and size of the various muscles and bones (and which are, as is well known, also found between lower and higher races of men) are due to differences in growth in consequence of divergent adaptation. On the other hand, the complete agreement in the construction of the whole motor apparatus is explained by heredity from the common stem-form of the apes and men. The most striking difference between the movements of the two is due to man's adaptation to the erect posture, while the climbing of trees is the normal habit of the ape. However, it is unquestionable that the former is an evolution from the latter. A double parallel to this modification is seen in the jerboa among the ungulates, and in the kangaroo among the marsupials. Both these, in springing, use only the strong hinder extremities, and not the weaker fore-limbs; as a result of this their posture has become

more or less erect. Among the birds we have an analogous case in the penguins *(aptenodytes)*; as they no longer use their atrophied wings for flight, but only in swimming, they have developed an erect posture when on land.

The human will is also not specifically different from that of the ape or any other mammal; and its microscopic organs, the neurona in the brain and the muscular cells in the flesh, work with the same forms of energy, and are similarly subject to the law of substance. Hence it is immaterial for the moment whether one believes in the freedom of the will according to the antiquated creed of indeterminism, or whether one holds it to be refuted scientifically by the arguments of modern determinists; in either case the acts of the will and voluntary movements follow the same laws in man as in the ape. The high development of the function in civilised man, the ample differentiation of speech and morality, art and science—in a word, the ethical significance of the will for higher culture—is in no way discordant to this monistic and zoologically grounded conception. In the lower races these privileges of the civilised will are only found in a slight degree, and some of them are wholly wanting among the lowest races. The distance between the lowest savage and the most civilised human being is greater, in this respect also, than that which separates the savage from the anthropoid ape. However, I refer the reader to the remarks I made at the close of the seventh chapter of the *Riddle* on the problem of the freedom of the will and the infinite literature relating thereto. The reader who desires to go further into this subject will find it well treated in the works of Traugott Trunk (1902) and Paul Rée (1903) [also in Dr. Stout's recent little manual of psychology and Mr. W. H. Mallock's *Religion as a Credible Doctrine*].

## Chapter XIII.

# SENSATION

Sensation and consciousness. Unconscious and conscious sensation. Sensibility and irritability. Reflex sensation and perception of stimuli. Sensation and living force. Reaction to stimuli. Resolution of stimuli. External and internal stimuli. Conveyance of stimuli. Sensation and striving. Sensation and feeling. Inorganic and organic sensation. Light sensation, phototaxis, sight. Sensation of warmth, thermotaxis. Sensation of matter, chemotaxis. Taste and smell. Erotic chemicotropism. Organic sensations. Sensation of pressure. Geotaxis. Sensation of sound. Electric sensation.

Sensation is one of those general terms that have at all times been liable to the most varied interpretations. Like the cognate idea of the "soul," it is still extremely ambiguous. During the eighteenth century it was generally believed that the function of sensation was peculiar to animals, and was not present in plants. This opinion found its most important expression in the well-known principle in Linné's *Systema Naturæ:* "Stones grow: plants grow and live: animals grow, live, and feel." Albrecht Haller, who gathered up all the knowledge of his time relating to organic life in his *Elementa Physiologiæ* (1766), distinguished as its two chief characters "sensibility" and "irritability." The one he ascribed exclusively to the nerves, and the other to the muscles. This erroneous idea was subsequently refuted, and in our own time irritability is conceived to be a general property of all living matter.

The great advance made by the comparative anatomy

and experimental physiology of animals and plants in the first half of the nineteenth century brought to light the fact that irritability or sensibility is a common quality of all organisms, and that it is one of the principal characteristics of vital force *(cf.* chap. ii.). The greatest merit in connection with its experimental study attaches to the famous Johannes Müller. In his classical *Manual of Human Physiology* (1840) he established his theory of the specific energy of the nerves and their dependence on the sense-organs on the one hand and the mental life on the other. He devoted the fifth chapter of his book to the former and the sixth to the latter, approaching particularly to Spinoza in his general psychological views; he treated psychology as a part of physiology, and thus put on a sound scientific basis that naturalistic conception of the place of psychology in the biological system which we now regard as the correct view. At the same time he proved that sensation is a function of the organism as much as movement or nutrition.

The view of sensation that prevailed in the second half of the nineteenth century was very different. On the one hand the experimental and comparative physiology of the sense-organs and the nervous system immensely enriched our exact knowledge by the invention of ingenious methods of research and the use of the great advance made by physics and chemistry. The famous investigations of Helmholtz and Hertwig on the physics of the senses, of Matteucci and Dubois-Reymond on the electricity of the muscles and nerves, and the great progress made in vegetal physiology by Sachs and Pfeffer, and in physiological chemistry by Moleschott and Bunge, enabled us to realise that even the most mysterious of the wonders of life depend on physical and chemical processes. By the application of the different stimuli—

light, heat, electricity, and chemical action—to the various sensitive or irritable organs under definitely controlled conditions, scientists succeeded in subjecting with exactness a great part of the phenomena of stimulation to mathematical measurements and formulæ. The science of the stimuli and their effects acquired a strictly physical character.

On the other hand, in most striking contradiction to the immense advance of experimental physiology, we see that the general conception of the various vital processes, and especially of the inner nerve-action that converts the functions of the senses into mental life, is most curiously neglected. Even the fundamental idea of sensation, which plays the chief part in it, is disregarded more and more. In many of the most valuable modern manuals of physiology, containing long chapters on stimuli and stimulation, there is little or no mention of sensation as such. This is chiefly due to the mischievous and unjustifiable gulf that has once more been artificially created between physiology and psychology. As the "exact" physiologists found the study of the inner psychic processes which take place in sense-action and sensation inconvenient and unprofitable, they gladly handed over this difficult and obscure field to the "psychologists proper"—in other words, to the metaphysicians, who had for the starting-point of their airy speculations the belief in an immortal soul and divine consciousness. The psychologists readily abandoned the inconvenient burden of experience and *à posteriori* knowledge, to which the modern anatomic physiology of the brain laid special claim.

The greatest and most fatal error committed by modern physiology in this was the admission of the baseless dogma that all sensation must be accompanied

by consciousness. As most physiologists share the view of Dubois-Reymond, that consciousness is not a natural phenomenon, but a hyperphysical problem, they leave it and this inconvenient "sensation" outside the range of their researches. This decision is, naturally, very agreeable to the prevalent metaphysics; it has just as much interest in the transcendental character of sensation as in the liberty of the will, and thus the whole of psychology passes from the empirical province of natural science into the mystical province of mental science. For its foundation they then take the "critical theory of knowledge," which ignores the results of the real physiological organs—the senses, nerves, and brain—and draws its "superior wisdom" from the inner mirroring of self by the introspective analysis of presentations and their associations. It is extraordinary that even distinguished monistic physiologists suffer themselves to be taken in with this sort of metaphysical jugglery, and dismiss the whole of psychology from their province; their psychomonism re-admits the soul as a supernatural entity, and delivers it, in contrast with the "world of bodies," from the yoke of the law of substance.

Impartial reflection on our personal experience during sensation and consciousness will soon convince us that these are two different physiological functions, which are by no means necessarily associated; and the same may be said of the third principal function of the soul—the will. When we learn an art—for instance, painting or playing the piano—we need months of daily practice in order to become expert at it. In this we experience every day hundreds of thousands of sensations and movements which are learned and repeated with full consciousness. The longer we continue the practice, and the more we adapt and accustom ourselves to the

function, the easier and less conscious it becomes. And when we have practised the art for some years, we paint our picture or play our piano unconsciously; we think no longer of all the small subtle shades of sensation and acts of will which were necessary in learning. The mere impulse of the will to paint the picture once more or play the piece again suffices to release the whole chain of complicated movements and accompanying sensations which had originally to be learned slowly, laboriously, and with full consciousness. An experienced pianist plays the most difficult piece—if he has learned it and repeated it thousands of times—"half in a dream." But it needs only a slight accident, such as a mistake or a sudden interruption, to bring back the wandering attention to the work. The piece is now played with clear consciousness. The same may be said of thousands of sensations and movements which we learned at first consciously in childhood, and then repeat daily afterwards without noticing—such as in walking, eating, speaking, and so on. These familiar facts prove of themselves that consciousness is a complicated function of the brain, by no means necessarily connected with sensation or will. To bind up the ideas of consciousness and sensation inseparably is the more absurd, as the mechanism or the real nature of consciousness seems very obscure to us, while the idea of it is perfectly clear: we know that we know, feel, and will.

The word "irritability" is generally taken by modern physiology to mean that the living matter has the property of reacting on stimuli—that is to say, of responding by changes in itself to changes in its environment. The stimulus, or action of a foreign energy, must, however, be felt by the plasm before the corresponding stimulated movement (in the form of

various manifestations of energy) will be produced. Hence the question whether this sensation is (in certain cases) associated with consciousness or (generally) remains unconscious is of a subordinate interest. The plant that is caused to open its floral calyx by the stimulus of light acts just as unconsciously in this as the coral that spreads out its crown of tentacles under the same influence; and when the sensitive carnivorous plant *(dionœa* or *drosera)* closes its leaves in order to catch and destroy the insect sitting on them, it acts in the same way as the sensitive actinia or coral when it draws in its crown of tentacles for the same object—in both cases without consciousness! We call these unconscious movements "reflex actions." I have dealt somewhat fully with these reflex movements in the seventh chapter of the *Riddle*, and must refer the reader thereto. This elementary psychic function always depends on a conjunction of sensation and movement (in the widest sense). The movement that the stimulus provokes is always preceded by a sensation of the influence exerted.

Modern physiology makes desperate efforts to avoid the use of the word "sensation" and substitute for it "perception of stimulus." The chief blame for this misleading expression is due to the arbitrary and unjustified separation of psychology from physiology. The latter is supposed to occupy itself with the material phenomena and physical changes, leaving to psychology the privilege of dealing with the higher mental phenomena and metaphysical problems. As we reject this distinction altogether on monistic principles, we cannot consent to separate sensation from the perception of stimuli—whether this sensation be accompanied with consciousness or not. Moreover, modern physiology, in

spite of its desire to keep clear of psychology, sees itself compelled in a thousand ways to use the words "sensation" and "sensitive," especially in the science of the organs of sense.

What we call sensation or perception of stimuli may be regarded as a special form of the living force or actual energy (Ostwald). Sensitiveness or irritability, on the other hand, is a form of virtual or potential energy. The living substance at rest, which is sensitive or irritable, is in a state of equilibrium and indifference to its environment. But the active plasm, that receives and feels a stimulus, has its equilibrium disturbed, and corresponds to the change in its environment and its internal condition. This response of the organism to a stimulus is called "reaction"—a term that is also used (in the same sense) in chemistry to express the interaction of bodies on each other. At each stimulation the virtual energy of the plasm (sensitiveness) is converted into living or kinetic force (sensation). The share of the stimulus in this conversion is described as a "release" of energy.

The term "reaction" stands in general for the change which any body experiences from the action of another body. Thus, for instance, to take the simplest case, the interaction of two substances in chemistry is called a reaction. In chemical analysis the word is used in a narrower sense to denote that action of one body on another which serves to reveal its nature. Even here we must assume that the two bodies feel their different characters; otherwise they could not act on each other. Hence every chemist speaks of a more or less "sensitive reaction." But this process is not different in principle from the reaction of the living organism to outer stimuli, whatever be their chemical or physical

nature. And there is no more essential difference in psychological reaction, which is always bound up with corresponding changes in the psychoplasm, and so with a chemical conversion of energy. In this case, however, the process of reaction is much more complicated, and we can distinguish several parts or phases of it: 1, the outer excitation; 2, the reaction of the sense-organ; 3, the conducting of the modified impression to the central organ; 4, the internal sensation of the conducted impression; and 5, consciousness of the impression.

The important idea of a release of energy—the term we give to the effect of the stimulus—is also used in physics. If we put a piece of burning wood in a barrel of powder, the flame causes an explosion. In the case of dynamite a simple mechanical shock is enough to produce the most enormous expenditure of force in the explosive matter. When we discharge a bow the slight pressure of the finger on the tense cord suffices to send out the arrow or bolt on its deadly mission. So also a sound or a ray of light that strikes the ear or eye suffices to bring about a number of complex effects by means of the nervous system. In the fertilisation of the ovum by the male sperm the chemical conjunction of the two formative principles is sufficient to cause the growth of a new human being out of the microscopic plasma-globule, the stem-cell *(cytula)*. In these and thousands of other reactions a very slight shock suffices to provoke the largest effects in the stimulated substance. This shock, which we call a release of energy, is not the direct cause of the considerable result, but merely the occasion for bringing it about. In these cases we have always a vast accumulation of virtual energy converted into living force or work. The magnitude of the two forces has no relation at all to the smallness of the shock which led to

the conversion. In this we have the difference between stimulated action and the simple mechanical action of two bodies on each other, in which the quantity of the energy expended is equal on both sides, and there is no stimulus.

The immediate effect of a stimulus on living matter can best be followed in external physical or chemical stimuli, such as light, heat, pressure, sound, electricity, and chemical action. In these cases physical science is often able to reduce the life-process to the laws of inorganic nature. This is more difficult with the internal stimuli within the organism itself, which are only partly exposed to physiological investigation. It is true that here also the task of science is to reduce all the biological phenomena to physical and chemical laws. But it can only discharge a part of this difficult task, as the phenomena are too complicated, and their conditions too little known in detail, to say nothing of the crudeness and imperfectness of our methods of research. Yet, in spite of all this, comparative and phylogenetic physiology convinces us that even the most complicated of our internal excitations, and particularly the mental activity of the brain, depend just as much as the outer stimulations on physical processes, and are equally subject to the law of substance. This is, in fact, true of reason and consciousness.

In man and all the higher animals the stimuli are received by the organs of sense and conducted by their nerves to the central organ. In the brain they are either converted into specific sensations in the sense-centres, or conveyed to the motor region, where they provoke movements. The conduction of stimuli is simpler in the lower animals and the plants; the tissue-cells either directly affect each other or are connected by fine threads

of plasm. In the unicellular protists the stimulus which strikes one particular spot of the surface may be immediately communicated to the other parts of the unified plasmic body.

We shall see in the course of our inquiry that the simplest form of sensation (in the widest sense) is common to inorganic and organic bodies, and thus that sensitiveness is really a fundamental property of all matter, or, more correctly, all substance. We may, therefore, ascribe sensation to the constituent atoms of matter. This fundamental thought of hylozoism, expressed long ago by Empedocles, has lately been very definitely urged, especially by Fechner. However, the able founder of psycho-physics (*cf.* the *Riddle*, p. 35) assumes that consciousness (or thought, in the Spinozistic sense) always accompanies this universal property of sensation. In my opinion, consciousness is a secondary psychic function, only found in man and the higher animals, and bound up with the centralisation of the nervous system. Hence it is better to speak of the unconscious sensation of the atoms as *feeling (æsthesis)*, and their unconscious will as *inclination (tropesis)*. It finds expression in the one-sided action of a stimulus as a "directed movement" or "stimulated movement" (*tropismus* or *taxis*).

The familiar ideas of sensation and feeling are often confused, and employed in very different ways in both physiology and psychology. The metaphysical tendency which so completely separates the two sciences, and the physiological tendency which agrees with it, regard feeling as a purely psychic or spiritual function, whereas in the case of sensation they have to admit the connection with bodily functions, especially sense-action. In my opinion, the two ideas are purely physiological and cannot

be sharply separated, or only in the sense that sensation relates more to the external (objective) part of the sensory nerve-process, and feeling to the internal (subjective) part. Hence we may define the difference in a general way by saying that sensation perceives the different qualities of the stimuli, and feeling only the quantity, the positive or negative action of the stimulus (pleasure or pain). In this last and widest sense we may ascribe the feeling of pleasure and pain (in the contact with qualitatively differing atoms) to all atoms, and so explain the elective affinity in chemistry (synthesis of loving atoms, inclination; analysis of hating atoms, disinclination).

Our monistic system (whether it be taken as energism or materialism, or more correctly as hylozoism) regards all substance as having "soul"—that is to say, endowed with energy. In the chemical analysis of organisms we do not find any elements that are not found in inorganic nature; we find that the movements in organisms obey the same laws of mechanics as the latter; we believe that the conversion of energy in the living matter occurs in the same way, and is provoked by the same stimuli, as in inorganic matter. We are forced to conclude from these experiences that the perception of stimuli—sensation in the objective and feeling in the subjective sense—is also generally present in the two. All bodies are in a certain sense "sensitive." It is just in this dynamic conception of substance that monism differs essentially from the materialistic system, which regards one part of matter as "dead" and insensitive. In this we have the best means of joining consistent materialism or realism with consistent spiritualism or idealism. But, as a first condition of such a union, we must demand a recognition that organic life is subject to the same

general laws as inorganic nature. In both cases the outer world acts alike as a stimulus on the inner world of the body. We can easily see this if we glance at the various kinds of sensation which corrrespond to the various kinds of stimuli. Light and heat, external and internal chemical stimuli, pressure and electricity, cause analogous sensations and modifications in their effect on organic and inorganic bodies.

The effect which the light-stimulus has on living matter, the sensation of light that results, and the chemical changes of energy that follow, are of great physiological importance in all organisms. We might even say that sun-light is the first, oldest, and chief source of organic life; all other exertions of force depend in the long run on the radiant energy of sun-light. The oldest and most important function of plasm—one which is at the same time a cause of its formation—is carbon-assimilation; and this plasmodomism is directly dependent on sun-light. If it acts in a one-sided way, it causes the particular form of stimulation which we call phototaxis or heliotropism. This is of a positive character—that is to say, they turn towards the source of the light—in the great majority of organisms, both protists and histona. Everybody knows that flowers that are growing in the window of a room turn to the light. However, many organisms which have grown accustomed to living in the dark are heliotropically negative; they shun the light and seek darkness, such as the fungi, many lucifugous mosses and ferns, and many deep-sea animals.

The principal organs of light-sensation in the higher animals are the eyes; they are wanting in many of the lower animals as well as the plants. The essential difference between the real eye and a part of the skin

that is merely sensitive to light is that the eye can form a picture of objects in the outer world. This faculty of vision begins with the formation of a small convergent lens, a bi-convex refracting body at a certain spot on the surface. Dark pigment-cells which surround it absorb the light-rays. From this first phylogenetic form of the organ of vision up to the elaborate human eye there is a long scale of evolutionary stages—not less extensive and remarkable than the historical succession of artificial optical instruments from the simple lens to the complicated modern telescope or microscope. This great "wonder of life"—the long scale of the evolution of the eye—has an interesting bearing on many important questions of general physiology and phylogeny. We can, in this case, see clearly how a very complicated and purposive apparatus can arise in a purely mechanical way, without any preconceived design or plan. In other words, we can see how an entirely new function—and one of its principal functions, vision—has arisen in the organism by mechanical means.

The advanced vision of the higher animals is made up of a great number of different functions, with a corresponding complexity of detail in the anatomic structure of the eye. No other organ, after the brain, is so necessary as the eye for the multifarious vital activities of the higher animals, and especially for the mental life of civilised man and the progress of art and science. What would the human mind be if we could not read, write, and draw, and have a direct knowledge through the eye of the forms and colours of the outer world? Yet this invaluable structure is only the highest and most perfect stage in the long chain of evolutionary processes which has its starting-point in the general sensitiveness to light, or the photic irritability of plasm. However, we find a

number of varieties and grades of this even among the unicellular protists, and indeed the very lowest and oldest of the protists, the monera. Various species of both the chromacea and the bacteria are heliotropic to different degrees, and have a fine sensitiveness to the strength of the light stimulus.

The stimulating effect which light has on the homogeneous plasm of the monera is also found in a number of inorganic bodies. In these cases the photic stimulus produces partly chemical and partly mechanical changes. Every chemist speaks of substances that are more or less "sensitive" to light; the photographer speaks of his "sensitive plates," the painter of his "sensitive colours." Many chemical compounds are so sensitive to light that they are destroyed at once in sun-light, and so have to be kept in the dark. There is no other word but "sensation" to express the attitude of the atoms towards each other which becomes so conspicuous in these cases under the influence of sun-light. It seems to me that this phenomenon is a clear justification of our hylozoic monism when it affirms that all matter is psychic. In metaphysics sensation is held to be an essential property of the soul.

In the same general way as light the heat-stimulus acts on organisms, and causes the sensations, sometimes pleasant and sometimes unpleasant, which we call the subjective feeling of heat, warmth, coolness, or cold. The sense-organ that receives these impressions of temperature is the surface of the unicellular plasmic body in the protists, and the skin (epidermis) that protects the surface from the outer world in the histona. In all living things the temperature of the surrounding medium (water or air) has a great influence in regulating the life-processes; in the stationary animals and plants

it is the temperature of the ground to which they are attached. This temperature must always be between the freezing point and boiling point of water, as fluid water is indispensable for the imbibition of the living matter and the molecular movements within the plasm. At the same time, some of the lower protists (chromacea, bacteria) can endure very high and very low temperatures, but only for a short time. Some protists (monera and diatomes) can stand a temperature of 200° C. for several days, and others can be heated above boiling point without being killed. Arctic and High-Alpine plants and animals may be in a frozen condition for several months, yet live again when they are thawed. However, the resistance to these extremes of cold lasts for only a limited time, and in the frozen state all vital functions are at a standstill.

In the great majority of living things the vital activity is confined within narrow limits of temperature. Many plants and animals in the tropics which have been accustomed for thousands of years to the constancy of the hot equatorial climate can endure only very restricted variations of temperature. On the other hand, many of the inhabitants of Central Siberia, where the climate is very hot in the short summer and very cold in the long winter, can stand great variations. Thus the living plasm has experienced considerable changes in its sense of warmth through adaptation to different environments; not only the maximum and the minimum, but the optimum (most agreeable point), is subject to very great variations. This can easily be observed and followed experimentally in the phenomena of thermotaxis or thermotropism—that is to say, the effect that follows from a one-sided action of the heat-stimulus. The organism that falls below the minimum of temperature

is said to be stiff with cold, while the organism that rises above the maximum is stiff with heat.

The heat-stimulus acts on inorganic as well as organic bodies, like the light-stimulus. The law holds good in both cases that higher temperatures increase sensation, while lower ones paralyse it. There is a minimum, an optimum, and a maximum, for many chemical and physical processes in the inorganic world. As far as the melting effect of water is concerned, freezing is the minimum of the heat stimulus and boiling the maximum. As the various chemical compounds meet in water at very different temperatures, we have an optimum for many substances—that is to say, a degree of warmth which is most favourable to the solution of a given quantity of a solid body in water. On the whole, the law holds for chemical processes that they are accelerated by high temperatures and retarded by low ones (like the human passions!); the former have a stimulating and the latter a benumbing effect. As the action of the various chemical compounds on each other is determined by the nature of the elements and their affinities, we must trace the variations in their conduct towards thermic stimuli to a sensation of temperature in the constituent atoms; increase of temperature stimulates it, while decrease lessens or paralyses it. Here, again, the simple inorganic processes have a general resemblance to the complicated vital phenomena in the organic body.

Since we regard the whole of organic life as, in the ultimate analysis, merely a very elaborate chemical process, we shall quite expect that chemical stimuli are the most important factors in sensation. And this is so in point of fact; from the simplest moneron up to the most highly differentiated cell and on to the flower in the plant and the mental life of man, the vital processes

are dominated by chemical forces and conversions of energy, which are set in play by external or internal chemical stimuli. The excitation which they produce is called in a general way "sensation of matter" or chemæsthesis; the basis of it is the mutual relation of the chemical elements which we describe as chemical affinity. In this affinity we have the play of attractive forces which lie in the nature of the elements themselves, especially in the peculiar properties of their constituent atoms; and this cannot be explained unless we ascribe unconscious sensation (in the widest sense) to the atoms, an inherent feeling of pleasure and the reverse, which they experience in the contact of other atoms (the "loves and hatreds of the elements" of Empedocles).

The numbers of different stimuli that act chemically on the plasm and excite its "sensation of matter" may be divided into two groups—external and internal stimuli. The latter lie within the organism itself, and cause the internal "organic sensations"; the former are in the outer world, and are felt as taste, smell, sex-impulse, etc. In the higher animals special chemical sense-organs have been developed for these chemical stimuli. As these are well known to us from our own human experience, and comparative physiology shows us the same structures in the higher animals, we will deal first with them. In general the same law holds for these external chemical stimuli as for optical and thermic stimuli; we can recognise a maximum limit of their action, a minimum below which they fail to stimulate, and an optimum or stage in which their influence is strongest.

The important part played in human life by taste and the pleasure associated with it is well known. The careful choice and preparation of savoury food—which has

become an art in gastronomy and a branch of practical philosophy in gastrosophy—was just as important 2,000 years ago with the Greeks and Romans as it is to-day in royal banquets or the Lucullic dinners of millionaires. The excitement that we see associated with this refined combination of rich foods and drinks, and that finds expression in so many speeches and toasts, has its philosophic root in the harmony of gustatory sensations and the varying play of stimuli that the delicate dishes and wines exercise on the organs of taste, the tongue and palate. The microscopic organs of these parts of the mouth are the gustatory papillæ—cup-shaped structures, covered with spindle-shaped "taste-cells," and having a narrow opening into the cavity of the mouth. When sapid matters, drinks and fluid or loose particles of food, touch the taste-cells, they excite the fine terminal branchlets of the gustatory nerve which enters the cells. As we find that there are similar structures in most of the higher animals, and that they also choose their food with some care, we may confidently assume that they have sensations of taste like man. However, no trace of this is found in many of the lower animals; in these cases it is impossible to lay down a line of demarcation between taste and smell.

In man and the higher air-breathing vertebrates the seat of the sense of smell is in the nostrils; in man it is especially that part of the mucus lining of the nasal cavity which we call the "olfactory region" (the uppermost part of the nasal dividing wall, the superior and middle meatus). It is necessary for a sensation of smell that the odorous matter, or olfactory stimuli, be brought in a finely divided condition over the moist olfactory membranes. When they touch the olfactory cells—slender, rod-shaped cells with very fine hairs at the free

end—they excite the ends of the olfactory nerve which are connected with the cells.

In many animals, especially mammals, the sense of smell has a much more important part in life than it has in man, in whom it is relatively feeble. It is well known that dogs and other carnivora, and even ungulates, have a much keener smell. In these cases the nasal cavity, which is the seat of the sense, is much larger, and the muscles in it are much stronger. The nostrils of the air-breathing vertebrates have been developed from a pair of open nasal depressions in the skin of the fish's head. But in these aquatic vertebrates the chemical action of the olfactory stimuli must be of a different character, like the sensation of taste. The odorous matter is, in these cases, brought into contact with the olfactory membrane in a liquid form (in which condition it is not perceptible to man). In fact, the division between the senses of smell and taste disappears altogether in the lower animals. These two "chemical senses" are closely related, and have a common feature in the direct chemical action of the stimulus on the sensitive part of the skin.

A chemical sensation of matter that corresponds completely to the real taste-sensation in the higher animals is found in some of the higher carnivorous plants. The leaves of the sun-dew *(drosera rotundifolia)* are very sensitive insect-traps, and are armed at the edge with knob-like tentacles, sticky hairs that secrete an acid flesh-digesting juice. When a solid body (but not a rain-drop) touches the surface of the leaf the stimulus acts in such a way on the tentacle heads as to contract the leaf. But the acid fluid which serves for digestion, and corresponds to the gastric juice in the animal, is only secreted by the corpuscles if the solid

foreign body is nitrogenous (flesh or cheese). Hence the leaves of these insectivorous plants taste their meat diet, and distinguish it from other solids, to which they are indifferent. In the broader sense, in fact, we may describe the points of the roots of plants as organs of taste; they plunge into the richer parts of the earth which yield more nourishment, and avoid the poor parts. In unicellular plants and animals the action of chemical stimuli is especially conspicuous when it is one-sided, and provokes definite movements in one particular direction *(chemotaxis)*.

The movements of unicellular organisms that are provoked by chemical stimuli and are known as chemotropism (more recently as chemotaxis) are particularly interesting because they show the existence of a chemical sensitiveness, somewhat resembling taste or smell, in the lowest organisms, and even in the homogeneous plasm of the monera. Repeated experiments of Wilhelm Engelmann, Max Verworn, and others, have shown that many bacteria, diatomes, infusoria, rhizopods, and other protists, have a similar sense of taste; they move towards certain acids (for instance, a drop of malic acid) or a bubble of oxygen that lies on one side of the drop of water in which the protists are under the microscope. Many pathogenetic bacteria secrete poisonous substances which are very injurious to the human frame. The active white blood-cells, leucocytes, in the human blood have a special "taste" for these bacteria-poisons, and concentrate in large quantities, by means of their amœboid movements, at those parts of the body where they are secreted. If the leucocytes prove the stronger in their struggle with the bacteria, they destroy them, and in this way they act as sanitary officers in keeping poisonous infection out of our organism. But if the

bacteria win the battle, they are transported into other parts of the body by the leucocytes; they distinguish their plasm by taste, and may cause a deadly infection.

We have a particularly interesting and important species of chemical irritation in the mutual attraction of the two sex-cells, to which I gave the name of chemotropism thirty years ago, and which I described as the earliest phylogenetic source of sexual love (see the *Anthropogeny*, chaps. vii. and xxix.). The remarkable phenomena of impregnation, the most important of all the processes of sexual generation, consist in the coalescence of the female ovum and the male sperm-cell. This could not take place if the two cells had not a sensation of their respective chemical constitution and disposition for union; they come together under this impulse. This sexual affinity is found at the lowest stages of plant life, in the protophyta and algæ. With these both cells—the smaller male microgameta and the larger female macrogameta—are often mobile, and swim about in order to effect a union. In the higher plants and animals only the small male cell is mobile as a rule, and swims towards the large immobile ovum in order to blend with it. The sensation that impels it is of a chemical nature, allied to taste and smell. This has been proved by the splendid experiments of Pfeffer, who showed that the male ciliated cells of ferns are attracted by malic acid, and those of the mosses by cane-sugar, just in the same way as by the exhalation from the female ovum. Conception depends on exactly the same erotic chemotropism in the fertilisation of all the higher organisms.

Erotic chemotropism must be regarded as a general sense-function of the sexual cells in all amphigonous

organisms, but in the higher organisms special forms of the sex-sense, connected with specific organs, are developed; as the source of sexual love they play a most important part in the life of many of the histona. In man and most of the higher animals these feelings of love are associated with the highest features of psychic life, and have led to the formation of some most remarkable customs, instincts, and passions. Wilhelm Bölsche has given us an admirable selection from this infinitely rich and attractive realm in his famous *Life of Love in Nature* (1903). It is well known that this sexual sense as we have it in man has been developed from the nearest related mammals, the apes. But while it offers a shameless and repulsive spectacle in many of the apes, it has been greatly ennobled and refined in man in the development of civilisation. However, the sexual sense-organs and their specific energy have remained the same. In the vertebrates and the articulates and many other metazoa the copulative organs are equipped with special cell-forms (voluptuous particles), which are the seat of intensely pleasurable feelings (see the *Anthropogeny*, chap. xxix., plate 30). The pubic hairs which clothe the *mons Veneris* are also delicate organs of the sex-sense, and so are the tactile hairs about the mouth. In these cases the correlation between the sensitive forms of energy in the copulative organs and the psychic functions of the central nervous system has been remarkably developed. Moreover, a large part of the rest of the skin may co-operate as a secondary organ of the sex-sense, as is seen in the effect of caressing, stroking, embracing, kissing, etc. Goethe, at once the greatest lyric poet and the subtlest and profoundest monistic philosopher of Germany, has given unrivalled expression to this sensual, yet supersensual, basis of sexual love. Ontogeny teaches

unmistakeably that its elementary organs, the epidermic cells, develop entirely from the ectoderm.

By "organic sensations" modern physiology understands the perception of certain internal bodily states, which are mostly brought about by chemical stimuli (to a small extent by mechanical and other irritation) in the organs themselves. As subjective feelings of the organism itself these states are most aptly called "feelings"—the positive states, pleasure, comfort, delight; the negative, discomfort, pain, etc. These organic sensations (also called common sensations or feelings) are of great importance for the self-regulation of the complicated organism. To the positive organic sensations belong, not only the bodily feeling of satiety, repose, or comfort, but also the psychic feelings of joy, good humour, mental rest, etc. Among negative common feelings we have not only hunger and thirst, bodily fatigue, bodily pain, sea-sickness, etc., but also mental strain, vertigo, bad humour, and so on. Between the two groups we have the third category of neutral organic sensations, which involve neither pleasure nor pain, but merely the perception of certain internal conditions, such as muscular strain (in lifting heavy objects), the disposal of the limbs (in crossing the legs), and so on.

Chemical sensation is just as general and important in organic nature as in the life of organisms. In this case it is nothing less than the basis of chemical affinity. No chemical process can be thoroughly understood unless we attribute a mutual sensation to the atoms, and explain their combination as due to a feeling of pleasure and their separation to a feeling of displeasure. The great Empedocles (fifth century B.C.) explained the origin of all things long ago by the various combination of pure elements, the interaction of love (attraction) and hate

(repulsion). This attraction or repulsion is, of course, unconscious, just as in the instincts of plants and animals. If one prefers to avoid the term "sensation," it may be called "feeling" *(æsthesis)*, while the (involuntary) movement it provokes may be called "inclination" *(tropesis)*, and the capacity for the latter "tropism" (more recently *taxis*, *cf.* chap. xii. of the *Riddle)*. We may illustrate it from the simplest case of chemical combination. When we rub together sulphur and mercury, two totally different elements, the atoms of the finely-divided matter combine and form a third and different chemical body, cinnabar. How would this simple synthesis be possible unless the two elements *feel* each other, move towards each other, and *then* unite?

We find universally distributed in nature the sensation of the mechanical stimulus of gravitation, the most comprehensive statement of which is given in Newton's law of gravity. According to this fundamental and all-ruling law, any two particles of matter are attracted in direct proportion to their mass and inverse proportion to the square of their distance. This form of attraction, also, can be traced to a "sensation of matter" in the mutually attracting atoms. The local sensation that any body provokes by contact with the surface of an organism is felt as pressure *(baros)*. A stimulus that causes this pressure alone brings about a counter-pressure as a reaction, and an effort to neutralise it, the pressure-movement *(barotaxis* or *barotropism)*. Sensitiveness to pressure or the contact of solid bodies is found throughout the organic world; it can be proved experimentally among the protists as well as the histona. Special sense-organs have been developed in the skin of the higher animals as the instruments of this pressure-sense (baræsthesis) in the form of tactile corpuscles;

they are most numerous at the finger-tips and other particularly sensitive parts. In many of the higher animals there is a fine sense of touch in the feelers or tentacles, or (in the higher articulates) in the horns or antennæ. Moreover, these tactile and prehensile organs are also very widely found among the higher plants, especially the climbing plants (vines, bryony, etc.). Their slender creepers, which roll out spirally, have a very delicate feeling for the nature of the supports which they embrace; they distinguish between smooth and rough, thick and thin, supports, and prefer the latter. Many of the higher plants, which are particularly sensitive to pressure, have, to an extent, special organs of touch (tentacles), and reveal this by the movements of their leaves (the sensitive plants, *mimosa*, *dionœa*, *oxalis*). But even among the unicellular protists we find that the contact of solid bodies has an irritating effect, the perception of which provokes corresponding movements (*thigmotaxis* or *thigmotropismus*). A peculiar form of pressure-sensation is produced in many organisms by the flow of liquids; in the mycetozoa, for instance, it provokes counter-movements (*rheotaxis*, *rheotropismus*), as Ernst Strahl showed by his experiments on *æthelium septicum*.

We have an interesting analogy to the thigmotaxis of the viscous living plasm in the elasticity of solid inorganic bodies, such as an elastic steel-rod. In virtue of its springy nature, the elastic rod reacts on the pressure of force that has bent it, and endeavours to regain its former position. The spiral spring sets the works of the clock in motion in virtue of its elasticity.

A very important part is played in botany by the action of gravitation on the growth of plants. The attraction towards the centre of the earth causes the

positively geotropic roots to grow vertically into the earth, while the negatively geotropic stalk pushes out in the opposite direction. This applies also to a number of stationary animals which are attached to the ground by roots, such as polyps, corals, bryozoa, etc. And even the locomotion of free animals, the disposition of their bodies to the ground, the position and posture of their limbs, etc., is determined partly by the feeling of gravitation, and partly by adaptation to certain functions which resist this, as in running, swimming, and so on. All these geotropic sensations belong to the same group of barotactile phenomena, as the fall of a stone or any other effect of gravitation that depends on an inorganic feeling of attraction.

As a result of these adaptations, we find a distinct sense of space developed in the higher, free-moving animals. The feeling of the three dimensions of space becomes an important means of orientation, and in the vertebrates, from the fishes up to man, the three spiral canals in the inner ear are developed as special organs of this. These three semi-circular canals, which lie vertically to each other in the three dimensions of space, are the organs of the sensation that guides the movements of the head, and, in relation to this, for the normal posture of the body and the feeling of equilibrium. If the three spiral canals are destroyed, the equilibrium is lost; the body totters and falls. Hence, these organs are not of an acoustic, but a static or geotactic character; and the same may be said of the so-called "auditory vesicles" of many of the lower animals—round vesicles which contain a liquid and a solid body, the otolith. When this body changes its position with the change of posture of the whole frame, it presses on the fine auditory hairs, or delicate terminations of the

auscultory nerve, which enters the vesicle. In fact, the sense of equilibrium is often combined with the sense of hearing.

The perception of noises and tones, which we call hearing, is restricted to a section of the higher, free-moving animals; if, that is to say, the above-mentioned "auditory vesicles" in the lower animals do not have acoustic as well as static sensations. The specific sensation of hearing is due to vibration of the medium in which the animal lives (air or water), or to vibrations of solid bodies (such as tuning forks) which are brought into touch with them. If the vibrations are irregular, they are felt as "noises"; if regular, they are heard as "tones" or notes; when a number of tones together (fundamental and over-tones) excite a complex sensation, we have "timbre." The vibrations of the sounding body are borne to the auditory cells, which represent the terminal extensions of the auscultory nerve. The specific sensation of hearing can, therefore, be traced originally to the sense of pressure, from which it has been evolved. As the organ of hearing is, like the eye, one of the principal instruments of the higher mental life, and as the refined musical hearing of civilised man is often taken to be a metaphysical power of the soul, it is important to note that here again the starting-point was purely physical; that is to say, it can be traced to the sense of pressure of matter, or gravitation.

The great importance of electricity as an agency in nature, both organic and inorganic, has only lately been fully appreciated. Electric changes are connected with many (if not, as is now supposed, with all) chemical and optical processes. Man himself and most of the higher animals have no electric organs (apart from the eye), and no sense-organs that experience a specific electric

sensation. It is probably otherwise with many of the lower animals, especially those that develop free electricity, such as the electric fishes. The larvæ of frogs and embryos of fishes, if put in a vessel of water through which a galvanic current is sent, place themselves when it is closed with their longitudinal axis in the direction of the current, with the head directed to the anode and the tail to the cathode (Hermann). Again, the luminous sea animals which cause the beautiful phenomenon of the illumination of the sea, and the glow-worms and other luminous organisms, have probably an unconscious feeling of the flow of electric energy associated with these phenomena. Many plants show a direct reaction to electric stimuli; when, for instance, we send a constant galvanic current for some time through the points of their roots (very sensitive organs, compared by Darwin to the brain of the animal), they bend towards the cathode.

Many of the protists are very sensitive to electric currents, as Max Verworn especially proved by a series of beautiful experiments. Most of the ciliated infusoria and many of the rhizopods *(amœba)* are cathodically sensitive or negatively galvanotactic. When we send a constant electric current through a drop of water in which thousands of *paramœcium* are moving about, all the infusoria swim at once, with the anterior pole of the body foremost, towards the cathode or negative pole; they accumulate about it in great crowds. If the direction of the current is now changed, the whole swarm at once make in the opposite direction for the new cathode. Most of the flagellate infusoria do just the reverse; they are anodically sensitive or positively galvanotactic. In a drop of water, in which swarms of *polytoma* are moving about, all the cells swim at once towards the anode or

positive pole, when an electric current is sent through. The opposite galvanotropic behaviour of these two groups of infusoria in a drop of water, in which they are mixed together, is very interesting; as soon as a constant stream enters it, the ciliata fly to the cathode and the flagellata to the anode. When the current is reversed the two swarms rush at each other like hostile armies, cross in the middle of the drop, and gather at the opposite poles. These and other phenomena of galvanic sensation show clearly that the living plasm is subject to the same physical laws as the water that is decomposed into hydrogen and oxygen by an electric current. Both elements *feel* the opposite electricities.

## SCALE OF SENSATION AND IRRITABILITY.

1st Stage: SENSATION OF ATOMS. Affinity of the elements in every chemical combination.

2nd Stage: SENSATION OF MOLECULES (groups of atoms): in the attraction and repulsion of molecules (positive and negative electricity, etc.).

3rd Stage: SENSATION OF PLASTIDULES (micella, biogens, or plasma-molecules): in the simplest vital process of the monera (chromacea and bacteria).

4th Stage: SENSATION OF CELLS: irritability of the unicellular protists (protophyta and protozoa): erotic chemotropism connected with the nucleus and trophic with the cell-body.

5th Stage: SENSATION OF CŒNOBIA (volvox, magosphæra). With the formation of cell-communities we have association of sensations (individual feeling on the part of the social cells together with common feeling on the part of the community).

6th Stage: SENSATION OF THE LOWER PLANTS. In the metaphyta or tissue-plants all the cells are still equally sensitive at the lower stages: there are no special sense-organs.

7th Stage: SENSATION OF THE HIGHER PLANTS. In the higher metaphyta specially sensitive cells, or groups of cells, with a specific energy, are developed at certain points: sense-organs.

8th Stage: SENSATION OF THE LOWER METAZOA, without differentiated nerves or sense-organs. Lower cœlenteria: sponges, polyps, platodaria.

9th Stage: SENSATION OF THE HIGHER METAZOA, with differentiated nerves and sense-organs, but still without consciousness (?). The higher cœlenteria and most of the cœlomaria.

10th Stage: SENSATION WITH DAWNING CONSCIOUSNESS, with independent formation of the phronema. The higher articulata (spiders and insects) and vertebrates (amphibia, lower reptiles, lower mammals).

11th Stage: SENSATION WITH CONSCIOUSNESS AND THOUGHT: amniotes: higher reptiles, birds, and mammals: savages.

12th Stage: SENSATION WITH PRODUCTIVE MENTAL ACTION IN ART AND SCIENCE: civilised men.

## Chapter XIV.

## MENTAL LIFE

Mind and soul. Intelligence and reason. Pure reason. Kant's dualism. Anthropology. Anthropogeny. Embryology of the mind. Mind of the embryo. The canonical mind. Legal rights of the embryo. Phylogeny of the mind. Paleontology of the mind. Psyche and phronema. Mental energy. Diseases of the mind. Mental powers. Conscious and unconscious mental life. Monistic and dualistic theory. Mental life of the mammals, of savages, and of civilised and educated people.

The greatest and most commanding of all the wonders of life is unquestionably the mind of man. That function of the human organism, to which we give the name of "mind," is not only the chief source of all the higher enjoyment of life for ourselves, but it is also the power that most effectually separates man from the brute according to conventional beliefs. Hence it is supremely important for our biological philosophy to devote a few careful pages to the study of its nature, its origin and development, and its relation to the body.

At the very outset of our psychological inquiry we are met by the difficulty of giving a clear definition of "mind," and distinguishing it from "soul." Both ideas are extremely ambiguous: their content and connotation are described in the most various ways by the representatives of science. Generally speaking, we mean by mind that part of the life of the soul which is connected with consciousness and thought, and is, therefore, only found in the higher animals which have intelligence and reason.

In a narrower sense reason is regarded as the proper function of mind, and as the essential prerogative of man in the animal world. In this sense Kant especially has done much to strengthen the prevailing conception of mental action, and has, by his *Critique of Pure Reason*, converted philosophy into a mere "science of reason." In consequence of this conception, which still prevails widely in scientific circles, we will first study the mental life in the action of reason, and try to form a clear idea of this great wonder of life.

Psychologists and metaphysicians are of very varied opinions as to the difference between intelligence and reason. Schopenhauer, for instance, considers causality to be the sole function of intelligence, and the formation of concepts to be the province of reason; in his opinion the latter power alone marks off man from the brute. However, the power of abstraction, which collects the common features in a number of different presentations, is also found in the higher animals. Intelligent dogs not only discriminate between individual men, cats, etc., according as they are sympathetic or the reverse, but they have a general idea of man or cat, and behave very differently towards the two. On the other hand, the power of forming concepts is still so slight in uncivilised races that it rises but little above the mind of dogs, horses, etc.; the mental interval between them and civilised man is extremely wide. However, a long scale of reason unites the various stages of association of presentations which lead up to the formation of concepts; it is quite impossible to lay down a strict line of demarcation between the lower and higher mental functions of animals, or between the latter and reason. Hence the distinction between the two cerebral functions is only relative; the intelligence comprises the narrower circle

of concrete and more proximate associations, while reason deals with the wider sphere of abstract and more comprehensive groups of association. In the scientific life of the mind, therefore, the intelligence is always occupied with empirical investigation, and reason with speculative knowledge. But the two faculties are equally functions of the phronema, and depend on the normal anatomic and chemical condition of this organ of thought.

Since Kant won so great a prominence in modern philosophy for the idea of pure reason by his famous *Critique* (1781), it has been much discussed, especially in the modern metaphysical theory of knowledge. It has, however, like all other ideas, undergone considerable changes of meaning in the course of time. Kant himself at first understood by pure reason "reason independent of all experience." But impartial modern psychology, based on the physiology of the brain and the phylogeny of its functions, has shown that there is no such thing as this pure *à priori* knowledge, independent of all experience. Those principles of reason which at present seem to be *à priori* in this sense have been attained in virtue of thousands of experiences. In so far as this is a question of real knowledge of the truth, Kant himself has frequently recognised the point. He says expressly in his *Prolegomena to any future metaphysic that can be regarded as Science* (1783, p. 204): "A knowledge of things by pure reason or pure intelligence is nothing but an empty appearance; only in experience is there truth." In subscribing to this empirical theory of knowledge of Kant I. and rejecting the transcendental theory of Kant II., we may on our side understand by pure reason "knowledge without prejudices," free from all dogma—all fictions of faith.

The familiar cry of modern metaphysicians, "Return

to Kant," has become so general in Germany that not only nearly all metaphysicians—the official representatives of "philosophy" at our universities—but also many distinguished scientists, regard Kant's dualistic theory of knowledge as a necessary condition for the attainment of truth. Kant dominated philosophy in the nineteenth century much as Aristotle did in the Middle Ages. His authority became especially powerful when the prevailing Christian faith believed that his "practical reason" fully supported its own three fundamental dogmas—the personality of God, the immortality of the soul, and the freedom of the will. It overlooked the fact that Kant had utterly failed to find proofs of these dogmas in his *Critique of Pure Reason*. Even conservative Governments found favourable features in this dualistic philosophy. We are, therefore, forced to return once more to this mischievous system; though Kant's antinomy of the two reasons has now been refuted so often and so thoroughly that we need not dwell any further on this point.

Although the great Könisberg philosopher brought every side of human life within his comprehensive sphere of study, man remained to him—as he had been to Plato and Aristotle, Christ and Descartes—a dual being, made up of a physical body and a transcendental mind or spirit. Comparative anatomy and evolution, which have provided the solid morphological basis of monistic anthropology, did not come into existence until the beginning of the nineteenth century; they were quite unknown to Kant. He had, however, a presentiment of their importance, as Fritz Schultze has shown in his interesting work on *Kant and Darwin* (1875). We find in various places expressions which may be described as anticipations of Darwinism. Kant also gave lectures

on "Pragmatic Anthropology," and studied the psychology of races and peoples. It is remarkable that he did not arrive at a phylogenetic conception of the human mind, and a recognition of the possibility of its evolution from the mind of other vertebrates. It is clear that he was held back from this by the profound mystic tendency of his theory of reason, and the dogma of the immortality of the soul, the freedom of the will, and the categorical imperative. Reason remained in Kant's view a transcendental phenomenon, and this dualistic error had a great influence on the whole structure of his philosophy. It must be remembered, of course, that our knowledge of the psychology of peoples was then very imperfect; but a critical study of the facts then known should have sufficed to convince him of the lower and animal condition of their minds. If Kant had had children, and followed patiently the development of the child's soul (as Preyer did a century later), he would hardly have persisted in his erroneous idea that reason, with its power of attaining *à priori* knowledge, is a transcendental and supernatural wonder of life, or a unique gift to man from heaven.

The root of the error is that Kant had no idea of the natural evolution of the mind. He did not employ the comparative and genetic methods to which we owe the chief scientific achievements of the last half-century. Kant and his followers, who confined themselves almost exclusively to the introspective method or the self-observation of their own mind, regarded as the model of the human soul the highly developed and versatile mind of the philosopher, and disregarded altogether the lower stages of mental life which we find in the child and the savage.

The immense advance made by the science of man

in the second half of the nineteenth century cut the ground from under the older anthropology and the dualistic system of Kant. A number of newly-founded branches of science co-operated in the work. Comparative anatomy showed that our whole complicated frame resembles that of the other mammals, and in particular differs only by slight stages of growth, and therefore in the details of the organs, from that of the anthropoid apes. The comparative histology of the brain especially showed that this is also true of the brain, the real organ of mind. From comparative embryology we learned that man developes from a simple ovum just like the anthropoid ape; in fact, that it is almost impossible to distinguish between the ape and the human embryo even at a late stage of development. Comparative animal chemistry explained that the chemical compounds which build up our organs, and the conversions of energy which accompany its metabolism, resemble those in the other vertebrates. Comparative physiology taught us that all man's vital functions—nutrition and reproduction, movement and sensation—can be traced to the same physical laws in man as in all the other vertebrates. Above all, the comparative and experimental study of the sense-organs and the various parts of the brain showed that these organs of the mind work in the same way in man as in the other primates. Modern paleontology taught that man is, it is true, more than a hundred thousand years old, but only appeared on earth towards the close of the Tertiary period. Prehistoric research and comparative ethnology have shown that civilised nations were preceded by older and lower races, and these by savages, which have a close bodily and mental affinity to the apes. Finally, the reformed theory of descent (1859) enabled us to unite

the chief results of the various branches of anthropological study, and explain them phylogenetically by the development of man from other primates (anthropoid apes, cynocephali, lemures, etc.). By this means a new and monistic basis was provided for modern anthropology; the position assigned to man in nature by dualistic metaphysics was shown to be utterly untenable. I have attempted in the last edition of my *Anthropogeny* [of which an English edition is in preparation] to combine all these results of empirical investigation in a sketch of the natural evolution of man, paying special regard to embryology. I pointed out in chaps. ii.–vi. of the *Riddle* how important a part of our monistic philosophy this phylogenetic anthropology is.

The monistic conception of the human body and mind, which the theory of descent has put on a zoological basis, was bound to meet with the sternest resistance in dualistic and metaphysical circles. It was, however, also regarded with great disapproval by many modern empirical anthropologists, especially those who take it to be their chief task to make as "exact" a study as possible of the human frame, and measure and describe its various parts. We might have expected these descriptive anthropologists and ethnologists to extend a friendly hand to the new anthropogeny, and avail themselves of its leading ideas, in order to bring unity and causal connection into the enormous mass of empirical material accumulated. However, this took place only to a limited extent. The majority of anthropologists regarded evolution, and especially the evolution of man, as an undemonstrated hypothesis. They confined themselves to accumulating huge masses of raw empirical material, without having any clear aim or any definite questions in view. This was chiefly the case in

Germany, where the Society of Anthropology and Prehistoric Research was for thirty years under the lead of Rudolph Virchow. This famous scientist had won great honour in connection with the reform of medicine by his cellular pathology and a number of distinguished works on pathological anatomy and histology since the middle of the nineteenth century. But when he afterwards (subsequently to his removal to Berlin, 1856) devoted himself chiefly to political and social questions, he lost sight of the great advance made in other branches of biology. He completely failed to appreciate its greatest achievement—the establishment of the science of evolution by Darwin. To this we must add the psychological metamorphosis (similar to that of Wundt, Baer, Du Bois-Reymond, and others), of which I have spoken in the sixth chapter of the *Riddle*. The extraordinary authority of Virchow, and the indefatigable zeal with which he struggled every year until his death (1903) against the descent of man from other vertebrates, caused a widespread opposition to the doctrine of evolution. This was supported especially by Johannes Ranke, of Munich, the secretary of the Anthropological Society. Happily, a change has recently set in. However, my *Anthropogeny* has remained for thirty years the only work of its kind—namely, a comprehensive treatment of man's ancestral history, especially in the light of embryology.

As I pointed out in the eighth and ninth chapters of the *Riddle*, the most solid foundation of our monistic psychology is the fact that the human mind grows. Like every other function of our organism, our mental activity exhibits the phenomenon of development in two directions, individually in each human being and phyletically in the whole race. The ontogeny of the

mind—or the embryology of the human soul—brings before us in direct observation the various stages of development through which the mind of every man passes from the beginning to the close of life. The phylogeny of the mind—or the ancestral history of the human soul—does not afford us this direct observation; it can only be deduced by a comparison and synthesis of the historical indications which are supplied by history and pre-historic research on the one hand, and the critical study of the various stages of mental life in savages and the higher vertebrates on the other. In this the biogenetic law is used with great success (chap. xvi.).

As everybody knows, the new-born child shows as yet no trace of mind or reason or consciousness; these functions are wanting in it as completely as in the embryo from which it has been developed during the nine months in the mother's womb. Even in the ninth month, when most of the organs of the human embryo are formed and arranged as they appear later, there is no more trace of mind in its psychic life than in the ovum and spermatozoon from which it was evolved. The moment in which these sexual cells unite marks precisely the real commencement of individual existence, and therefore of the soul also (as a potential function of the plasm). But the mind proper—or reason, the higher conscious function of the soul—only developes, slowly and gradually, long after birth. As Flechsig has shown anatomically, the cortex in the new-born child is not yet organised or capable of functioning. Rational consciousness is even impossible for the child when it begins to speak; it reveals itself for the first time (after the first year) at the moment when the child speaks of itself, not in the third person, but as "I." With this self-consciousness comes also the antithesis of the individual to

the outer world, or world-consciousness. This is the real beginning of mental life.

In defining the appearance of the individual mind by the awakening of self-consciousness, we make it possible to distinguish, from the monistic physiological point of view, between "soul" *(psyche)* and "spirit" *(pneuma)*. There is a soul even in the maternal ovum and the paternal spermatozoon (*cf.* chap. xi.); there is an individual soul in the stem-cell *(cytula)* which arises at conception by the blending of the parent cells. But the mind proper, the thinking reason, developes out of the animal intelligence (or earlier instincts) of the child only with the consciousness of its personality as opposed to the outer world. At the same time the child reaches the higher stage of personality, which law has for a long time taken under its protection and made morally responsible to society by education. This shows how erroneous and untenable, from the physiological point of view, are the ideas still embodied in our code as to the psychic life and the mind of the embryo and the newborn infant. They came mostly from the Canon Law of the Catholic Church.

The dualistic ideas of the soul of the human embryo which were taught by the Church in the Middle Ages are particularly interesting from the psychological point of view; and, at the same time, they are of great practical importance even in our own day, since many of their moral consequences form an important element in Canon Law, and have passed from this into Civil Law. This influential Canon Law was formed under ecclesiastical authority from the decisions of Church Councils and the decretals of the popes. It is, like most of the dogmas and decrees which civilisation owes to this powerful hierarchy, a curious tissue of old traditions and new

fictions, political dogmas, and crass superstition. It is directed to the despotic ruling of the uneducated masses and the exclusive dominion of the Church—a Church that calls itself Christian while thus acting as the very reverse of pure Christianity. The Canon Law takes its name from the dogmatic rules (or canons) of the Church. They involuntarily suggest the metal tubes which are so often the *ultima ratio regis* in the wars of Christian nations. The canonical regulations of the Church, as implements of a crude spiritual despotism, have no more to do with the ethical laws of pure reason than the cannons of secular authorities have as naked organs of physical force. We might write the motto, *Ultima ratio ecclesiæ* (the last argument of the Church), over the sacred *Corpus Juris Canonici*. A collection of later papal decretals which forms an appendix to the books of Canon Law was very happily given the official title of *Extravagantes*. Among the "extravagant" nonsense which the papacy included in Canon Law as a moral code for believers is its view of the psychic life of the embryo. The "immortal soul" is supposed to enter the soul-less embryo only several weeks after conception. As theologians and metaphysicians are very much divided as to the period of this entrance of the soul, and know nothing about the structure of the embryo and its development, we will only recall the fact that the human fœtus cannot be distinguished from that of the anthropoid ape and other mammals even in the sixth week of its development. The outline of the five cerebral vesicles and the three higher sense-organs (nose, eye, and ear-vesicle) is discernible in the head; the two pairs of limbs can be traced in the shape of four simple roundish unjointed plates; and the pointed tail sticks out at the lower part, the rudimentary legacy from our long-tailed

ape-ancestors. Although the cortex is not yet developed at this stage, the embryo may be considered to have a "soul" (*cf.* chaps. xiv. and xv. of my *Anthropogeny*, and plates 8–14).

It is said to be a great merit of Canon Law that it was the first to extend legal protection to the human embryo, and punished abortion with death as a mortal sin. But as this mystical theory of the entrance of the soul is now scientifically untenable, we should expect them consistently to extend this protection to the fœtus in its earlier stages, if not to the ovum itself. The ovary of a mature maid contains about 70,000 ova; each of these might be developed into a human being under favourable circumstances if it united with a male spermium after its release from the ovary. If the State is so eager for the multiplication of its citizens in the general interest, and regards prolific reproduction as a "duty" of its members, this is certainly a "sin of omission." It punishes abortion with several years' imprisonment. But, while Civil Law thus takes its inspiration from Canon Law, it overlooks the physiological fact that the ovum is a part of the mother's body over which she has full right of control; and that the embryo that developes from it, as well as the new-born child, is quite unconscious, or is a purely "reflex machine," like any other vertebrate. There is no mind in it as yet; it only appears after the first year when its organ, the phronema in the cortex, is differentiated. This interesting fact is explained by the biogenetic law, which shows that the ontogeny of the brain is a condensed recapitulation of its phylogeny in virtue of the laws of heredity.

The biogenetic law applies just as much to the brain, the organ of mind, as to any other organ of the human

body. On the strength of the ontogenetic facts, which fall under direct observation, we infer that there was a corresponding development in the phylogenetic series of our animal ancestors. A significant confirmation of this inference is found in comparative anatomy. It shows that in all the skull-animals *(craniota)*—from the fishes and amphibia up to the apes and man—the brain is developed in the same way, as a vesicular distension of the ectodermal medullary tube. This simple oval cerebral vesicle first divides into three and afterwards five successive vesicles by transverse constriction (*Anthropogeny*, chap. xxiv., plate 24). It is the first of these vesicles, the cerebrum, that afterwards becomes the chemical laboratory of the mind. In the lower craniota (fishes and amphibia) the cerebrum remains very small and simple. It only reaches a notably higher stage in the three chief classes of the vertebrates, the amniotes. As these land-dwelling and air-breathing craniota have more difficult work to do in the struggle for life than their lower aquatic ancestors, we find much more varied and complex habits among them. These hereditary habits are gradually converted into instincts by functional adaptation and progressive heredity; and with the further development of consciousness in the higher mammals we have at last the appearance of reason. The gradual unfolding of the mental life is accompanied step by step with the advance of its anatomic organ, the phronema in the cortex. Recent careful investigations of the ontogeny and histology of the origin of mind (by Flechsig, Hitzig, Edinger, Ziehen, Oscar Vogt, etc.) have given us an interesting insight into the mysterious processes of its phylogeny.

While the comparative anatomy of the cortex gives us a good idea of the gradual historical development of the

mind in the higher classes of vertebrates, we get at the same time from their fossilised remains positive indications as to the period of time in which this phylogenesis has slowly taken place. The historical series in which the classes of vertebrates have succeeded each other in the great periods of the organic history of the earth is directly demonstrated by their fossil remains—the real commemorative medals of natural creation—and gives us a most valuable record of the ancestral history of our race and of the mind. The oldest strata that contain vertebrate remains form the huge Silurian system, which were, on the latest calculations, formed more than a hundred million years ago. They contain a few fossil fishes. In the succeeding Devonian system these are followed by the dipneusta, transitional forms between the fishes and the amphibia. The latter, the oldest four-footed and five-toed vertebrates, appear in the Carboniferous period. They are succeeded in the Permian, the next system, by the oldest amniotes, the primitive reptiles (tocosauria). It is not until the next period (the Triassic) that the oldest mammals are found, small primitive monotremes *(pantotheria)*, then marsupials in the Jurassic, and the first placentals in the Cretaceans. The great wealth of varied and highly organised forms which are contained in this third and last subclass of the mammals appear only in the succeeding Tertiary period. The numbers of well-preserved skulls which these placentals have left behind in fossil form are particularly important, because they give us an idea of the quantitative and qualitative formation of the brain within the various orders; thus, for instance, in the modern carnivora the brain is from two to four times, and in the modern ungulates from six to eight times, as large (in proportion to the size of the body) as in their

earliest Tertiary ancestors. It is also found that the cortex (the real organ of mind) has developed in the Tertiary period at the expense of the other parts of the brain. The duration of this cœnozoic period has lately been calculated at 3,000,000 years (according to other geologists twelve to fourteen or more million years). It was, at all events, sufficient to make possible the gradual development of the human mind from the lower intelligence of our ape-ancestors and the instincts of the older placentalia.

We have given the physiological name of the "phronema," as the real organ of mind or the instrument of reason, to that part of the cortex on the normal anatomic condition of which the action of the human mind depends. The remarkable investigations during the last few decades of the finer texture of the grey cortex (or cortical substance of the cerebrum) have shown that its structure—a real anatomic "wonder of life"—represents the most perfect morphological product of plasm; and its physiological function—mind—is the most perfect action of a "dynamo-machine," the highest achievement that we know anywhere in nature. Millions of psychic cells or neurona—each of them of an extremely elaborate fibril molecular structure—are associated as special thought-organs (phroneta) at certain parts of the cortex, and these again are built up into a large harmonious system of wonderful regularity and capacity. Each phronetal cell is a small chemical laboratory, contributing its share to the unified central function of the mind, the conscious action of reason. Scientists are still very far from agreement as to the extent of the phronema in the cortex and its delimitation from the neighbouring sense-centres (sensoria). But they are all agreed that there is such a central organ of mind, and

that its normal anatomic and chemical condition is the first requisite for the life of the human mind. This belief—one of the foundations of monistic psychology—is confirmed by the study of psychiatry.

The study of the diseased organism has greatly furthered our knowledge of the normal frame. Diseases are so many physiological experiments made by nature herself under special conditions, which experimental physiology would often be unable to arrange artificially. The thoughtful physician or pathologist can often obtain most important knowledge of the function of organs by carefully observing them during disease. This is especially true of diseases of the mind, which always have their immediate foundation in an anatomical or chemical modification of certain parts of the brain. Our advancing knowledge of the localisation of mental functions, or of their connection with special phroneta or organs of thought, is for the most part based on the experience that the destruction of the one is followed by the extinction of the other. Modern psychiatry, the empirical science of mental disease, has thus become an important element of our monistic psychology. If Immanuel Kant had studied it and had visited the asylum wards for a few months, he would certainly have escaped the dualist errors of his philosophy. We may say the same of the modern metaphysical psychologists who built up a mystic theory of an immortal soul without knowing the anatomy, physiology, and pathology of the brain.

The comparative anatomy, physiology, and pathology of the brain, in concurrence with the results of ontogeny and phylogeny, have led us to form the sound monistic principle that the human mind is a function of the phronema, and that the neurona of the latter, or the phronetal cells, are the real elementary organs of mental

life. Hence modern energism is perfectly justified in regarding mental energy (in all its forms) from the same point of view as all other forms of nervous energy, and in fact all manifestations of energy in organic or inorganic nature. Fechner's psychophysics had already shown that a part of this nervous energy is measurable and mathematically reducible to the mechanical laws of physics *(Riddle*, chap. vi.). Ostwald has, in his *Natural Philosophy*, lately emphasised the fact that all the manifestations of mental life, not only sensation and will, but even thought and consciousness, can be reduced to nervous energy. Hence we may distinguish what are called mental forces from the other expressions of nervous energy as *phronetic energy*. The monistic research of Ostwald on the energy-processes in mental life (chap. xviii.), consciousness (chap. xix.), and will (chap. xx.) is very notable, and confirms the views I advanced in the second part of the *Riddle* (chaps. vi., x., and xi.). Ostwald has, however, caused some misunderstanding by insisting on substituting his idea of energy for the pure notion of substance (as Spinoza had formulated it), and by rejecting the other attribute of substance, matter. His supposed "Refutation of Materialism" is a mere attack on wind-mills; his energism (the consistent dynamism of Leibnitz, etc.) is just as one-sided as its apparent opposite, the consistent materialism of Democritus, Holbach, etc. The latter makes matter precede force; the former regards matter as the product of force. Monism escapes the one-sidedness of both systems, and, as hylozoism, refuses to separate the two attributes of substance, space-filling matter and active energy. This applies to mental life just as to any other natural process; our mental forces or phronetic energies are just as much bound up with the neuroplasm, the living plasm of

the neurona in the cortex, as the mechanical energy of our muscles is with the contractile myoplasm, the living muscular substance.

In the exhaustive study of consciousness which I gave in the tenth chapter of the *Riddle* I sought to show that this enigmatic function—the central mystery of psychology—is not a transcendental problem, but a natural phenomenon, subject to the law of substance, as much as any other psychic power. The child's consciousness only developes long after its first year, and grows as gradually as any other psychic function; like these, it is bound up with the normal anatomic and chemical condition of its organs, the phroneta in the cortex. Consciousness developes originally out of unconscious functions (as an "inner view," or mirroring, of the action of the phronema); and at any time an unconscious process in the cortex may come within the sphere of consciousness by having the attention directed to it. On the other hand, conscious actions, which need a good deal of attention when they were first learned (such as playing the piano), may become unconscious through frequent repetition and practice. The fact that chemical energy is converted in the phronetal cells during any of these actions is proved by the fatigue and exhaustion which prolonged mental work causes in the brain, just as mechanical work does in the muscles. Fresh matter has to be supplied by the food before the mental work can be continued. Moreover, it is well known that various drinks have a considerable influence on consciousness (coffee and tea, beer and wine); and the temporary extinction of it under chloroform or ether is an analogous fact. Again, the familiar phenomena of the dream, the deviations from normal consciousness, hallucinations, delusions, etc., must convince every impartial thinker

that these mental functions are not of a metaphysical character, but physical processes in the neuroplasm of the brain, and thoroughly dependent on the law of substance.

In complete contrast to this natural monistic conception of the human mind, which is, in my opinion, definitely established by nineteenth-century science, we have the older dualistic estimate of it which is still widely accepted both by unlearned and learned, especially metaphysicians and theologians. I have already dealt in the *Riddle* (chap. xi.) with the grounds for this belief in an immaterial soul, and expressed my conviction that "the belief in the immortality of the human soul is in flagrant contradiction to the soundest empirical principles of modern science." I must refer the reader to what I said there about thanatism and athanatism, only reminding him once more of the immense influence of the Kantist philosophy in maintaining this belief in the spirituality of the soul. Kant derived from the introspective study of his own gifted mind an extremely high estimate of human reason, and he fallaciously transferred this estimate to the human mind generally. He did not perceive that it is either wholly wanting in the savage, or does not rise much above the stage which has been reached by the intelligence of the dog, horse, elephant, and other advanced animals.

Modern anthropogeny has raised the theory of evolution to the rank of an historical fact. All the various organs of our body resemble those of our nearest relatives, the anthropoid apes, in their structure and composition. They only differ from them in details of form and size, which are determined by inherited variations of growth. But the functions as well as the organs have been inherited by man from his primate ancestors. This

applies to the mind also, which is merely the collective function of the phronema, the central organ of thought. An impartial comparison of mental life in the anthropoid ape and the savage shows that the differences between the two are not more considerable than the differences in the structure of their brains. Hence, if one accepts the dualistic theory of the soul formulated by Plato and Kant and accepted by so many modern psychologists, it is necessary to attribute an immortal soul to the anthropoid apes and the higher mammals (especially to domestic dogs) just as well as to savage or civilised man (*cf.* chap. xi. of the *Riddle*).

The thorough and careful study of the mental life of the savage, supported by the results of anthropogeny and ethnography, has in the course of the last forty years decided the issue of this struggle between the conflicting theories of the origin of civilisation. The older theory of degeneration, based on religious beliefs, and so preferred by theologians and theosophists, declared that man—the "image of God"—was created originally with perfect bodily and mental powers, and only fell away from his high estate after the original sin. On this view the present savages are degenerate descendants of the first god-like men. (In tropical lands the anthropoid apes are in similar fashion regarded by the natives as degenerate branches of their own stem!) Although this Biblical degeneration theory is still taught in most of our schools, and even supported by a few mystic philosophers, it had lost all scientific countenance before the end of the nineteenth century. It is now replaced by the modern theory of evolution, which was represented by Lamarck, Goethe, and Herder a century ago, and raised to a predominant position in ethnography by Darwin and Lubbock. It has taught us that human

civilisation is the outcome of a long and gradual process of evolution, covering thousands of years. The civilised races of our time have arisen from less civilised races, and these in turn from lower, until we reach the savage races which show no trace of civilisation.

Ethnologists distinguish as a separate class the races which are found midway between the civilised peoples and the savages. We shall deal with their classification and characteristics later on (chap. xvii.). These races show some advance on the artistic instinct which we find in a slight degree even among the savages at times; moreover, their animal curiosity developes into human curiosity, and raises the question of the causes of phenomena, the germ of all science.

Civilised races, which occupy the next stage to these, are raised above them by the formation of larger states and a greater division of labour. The specialisation of the various groups of workers and the greater ease of maintenance permit a further development of art and science. To these groups belong, of living races, the majority of the Mongolians, and the greater part of the inhabitants of Europe and Asia in ancient and medieval times. The great ancient civilisations of China, Southern India, Asia Minor, Egypt, and afterwards of Greece and Italy, show not only a great development of art and science, but also a concern for legislation, religious worship, education of the young, and the spread of knowledge by written books.

Civilisation in the narrower sense, characterised by a high development of art and science and the manifold application of them to practical life in legislation, education, etc., was greatly advanced even in antiquity among several nations; in Asia by the Chinese, Southern Indians, Babylonians, and Egyptians, in Europe by the

Greeks and Romans of the classic age. However, their results were at first restricted to narrow fields, and were mostly lost during the Middle Ages. Modern civilisation rose to importance about the end of the fifteenth century, when the invention of printing had made possible the spread of knowledge far and wide, the discovery of America and circumnavigation of the globe had widened the horizon, and the Copernican system had demolished the error of geocentricism. Then began the many-sided growth of civilisation which has reached so marvellous a height in the nineteenth century through the extraordinary development of science. Then at last free reason could triumph over the prevailing medieval superstition.

## Chapter XV.

# THE ORIGIN OF LIFE

The miracle of the origin of life. Creation of species: Moses and Agassiz. Creation of the first cells: Wigand and Reinke. Agnostic position—resignation. Eternity hypothesis (dualistic, Helmholtz; monistic, Preyer). Archigony hypothesis (autogony hypothesis, Haeckel, Naegeli; cyanic hypothesis, Pflüger, Verworn). Spontaneous generation. Saprobiosis or necrobiosis. Experiments in spontaneous generation. Pasteur. Stages of archigony. Observation of archigony. Synthesis of plasma. Value of the unsuccessful experiments to produce plasm artificially. The logic of modern experimental biology.

The question of the origin of life is one of the most important and interesting, but one of the most difficult and complicated, problems with which the mind of man has been occupied for thousands of years. There are few other questions (such as the freedom of the will or personal immortality) on which such different and contradictory views have been expressed, and few that remain so far from being closed at the present day. There are, moreover, few problems on which the opinions of even distinguished thinkers diverge so much, and have degenerated so much into fantastic hypotheses. This is partly due to the extreme difficulty of giving a strictly scientific solution of the problem, and partly to the confusion of ideas which is so great in this controversy, the lack of clear rational insight, and the powerful authority of the prevailing religious faith and other venerable dogmas.

The easiest and quickest thing to do is to cut the Gordian knot of the question with the sword of faith, or answer it with a belief in a supernatural creation. The first article of the creed was given to us in childhood as the foundation of all cosmic philosophy. It is based on the Mosaic account of creation in the first chapter of Genesis. As I have fully examined its scientific value in the second chapter of my *History of Creation*, I may refer the reader thereto. It is unquestionable that this myth still has a very great practical influence; the great majority of the clergy cling to it because it is found in the infallible "word of God." Most Governments, which hold blind faith to be an important element of education, include it in the code for the elementary school. On the other hand, it is difficult to find a man of science who will uphold it to-day. The gifted Louis Agassiz made one of the most remarkable attempts to do this in his *Essay on Classification* (1858), a book that appeared almost contemporaneously with Darwin's epoch-making *Origin of Species*, and dealt with the general problems of biology from the directly opposite, the mystic, point of view. According to Agassiz, each species of animal or plant is an "incarnate thought of the Creator."

Differing from this Biblical fancy of the supernatural creation of each species, two botanists, Wigand of Marburg and Reinke of Kiel, have lately restricted the action of the celestial architect very considerably; they have ascribed to him only the creation of the primitive cells, which he is supposed to have endowed with the power to develop into the higher organisms. Wigand assumed for the origin of each species a special primitive cell and a long phylogenetic development of this; Reinke prefers a stem, composed of a number of species. These modern creative theories have no more scientific value

than that of Agassiz; they are equally based on pure superstition (*cf.* chaps. i.–iii.).

A different attitude from this irrational positive superstition is the sceptical view of those scientists who regard the question of the origin of life as insoluble or transcendental. Darwin and Virchow are representatives of this Agnostic position; they held that we know nothing, and can know nothing, about the origin of the first organisms. Darwin, for instance, explains in his chief work that he "has nothing to do with the origin of the fundamental spiritual forces, or with that of life itself." This is a complete abandonment of the task of solving a scientific problem which must present as definite a subject of inquiry to modern research as any other evolutionary problem. The origin of life on our planet represents a fixed point in its history. However, there is nothing to be said if a scientist chooses to make no inquiry into it. A number of distinguished modern scientists maintain this Agnostic attitude; they are more or less convinced that the origin of life is a natural process, but believe we have not as yet the means to explain it.

Different, again, is a third attitude which regards the problem of the origin of life as extremely difficult, yet capable of solution. This is the position of Dubois-Reymond, for instance, who counts the origin of life as the third great cosmic problem. Most of the modern scientists who have worked on the problem are of this opinion, although their views as to the way of solving it differ very much. We are confronted, in the first place, with two essentially different views which we may call the eternity-hypothesis and the theory of archigony (or spontaneous generation). According to the first view, organic life is eternal;

according to the second, it began at a definite point of time. The eternity-hypothesis has assumed two very different forms, one of which has a dualistic and the other a monistic base. Helmholtz is a representative of the former theory, and Preyer of the latter.

Hermann Eberhard Richter put forward, in 1865, the hypothesis that infinite space is full throughout of the germs of living things, just as it is of inorganic bodies; both of them are in a condition of eternal development. When the ubiquitous germs reach a mature and habitable cosmic body, which possesses heat and moisture in the proper degrees for their development, they break into life, and may lead to the formation of a whole world of living things. Richter conceives these ubiquitous germs as living cells, and formulates the principle: *Omne vivum ab æternitate e cellula* (Every living thing is eternal and from a cell). In much the same way the botanist Anton Kerner postulates the eternity of organic life and its complete independence of the inorganic world. But the difficulties encountered by this hypothesis, in the indefinite form that Kerner gives it, are so great and so obvious that his theory has won no recognition.

However, the "cosmozoic hypothesis" attained a great popularity when it was afterwards taken up by two of the most distinguished physicists, Hermann Helmholtz and Sir W. Thomson [Lord Kelvin]. Helmholtz formulated the alternative thus (in 1884): "Organic life either came into existence at a certain period, or it is eternal." He declared for the latter view, on the ground that we have not succeeded in producing living organisms by artificial means. He supposes that the meteors that roam about the universe might contain the germs of organisms, and, under favourable conditions, these might

reach the earth or other planets and develop thereon. This cosmozoic hypothesis of Helmholtz is untenable, because the physical features of space (the extreme temperatures, the absolute dryness, the absence of atmosphere, etc.) exclude the lasting existence of plasm on meteorites in the form of organic germs with a capacity to live. The hypothesis is, moreover, logically useless, since it does not solve, but postpones, the question of the origin of organic life. If it is consistently worked out, it leads to pure cosmological dualism.

Another and very different theory of the eternity of life has been elaborated by Theodor Fechner (1873) and Wilhelm Preyer (1880). Both these scientists extend the idea of life to the whole cosmos, and reject the distinction that is usually drawn between the organic and the inorganic. Fechner goes so far as to ascribe consciousness to the whole universe and every single body in it, and regards individual organisms merely as parts of one vast universal organism. His system is, therefore, panpsychistic, and, at the same time, pantheistic, as he somewhat mystically connects the idea of a conscious God with that of a living universe. Preyer generally agrees with him in extending the idea of life to the whole universe, and conceiving it as an organism. He applies his theory in the symbolic sense which I alluded to on p. 38, and described as impracticable. The fiery mass of the forming earth is the gigantic organism, and Preyer gives the name of "life" to its rotatory movement (or gravitational energy). As it cooled down, the heavier metals (the dead inorganic masses) separated from it; from the rest of it were formed first simple and afterwards complex carbon-combinations, and finally albumin and plasm. This extension of the word "organism" has very properly met with little

approval in biology. It only increases the confusion, and the difficulty of marking off biological from abiological science, which is both practically necessary and theoretically justified.

If, then, in our opinion, the eternity-hypotheses are of no more value than the creation-hypotheses, we have left, for the purpose of answering the great question of the origin of life, only the third group of scientific theories which I have combined under the general head of archigony. They start from the following points:— 1. Organic life is everywhere bound up with the plasm (or protoplasm), a chemical substance of a viscous character, having albuminous matter and water as its chief constituents. 2. The characteristic movements of this living substance, to which we give the name of organic life, are physical and chemical processes, that can only take place within certain limits of temperature (between the freezing-point and boiling-point of water). 3. Beyond these limits organic life may in certain circumstances be maintained for a time in a latent condition (apparent death, potential life); but this latent condition is restricted to a certain (and generally short) period. 4. As the earth, like all the other planets, was for a long time in a state of incandescence, at a temperature of several thousand degrees, living organisms (viscous albuminoids) cannot possibly have existed on it, and so cannot be eternal. 5. Fluid water, the first condition for the appearance of organic life, cannot have formed on it until the crust at the surface had fallen below boiling-point. 6. The chemical processes which first set in at this stage of development must have been catalyses, which led to the formation of albuminous combinations, and eventually of plasm. 7. The earliest organisms to be thus formed can only have been plasmodomous monera, structureless

organisms without organs; the first forms in which the living matter individualised were probably homogeneous globules of plasm, like certain of the actual chromacea *(chroococcus)*. 8. The first cells were developed secondarily from these primitive monera, by separation of the central caryoplasm (nucleus) and peripheral cytoplasm (cell-body).

The monistic hypothesis of abiogenesis, or autogony [= self-development] in the strictly scientific sense of the word, was first formulated by me in 1866 in the second book of the *General Morphology*. The solid foundation for it was found in the monera I had described, the very simple organisms without organs that had up to that time been overlooked or thrust aside. It is of radical importance, in giving a naturalistic solution of the problem of the origin of life, to start from these structureless granules of living matter, and not—as still generally happens—from the cell; these nucleated elementary organisms could not be the earliest archigonous living things, but must have been evolved secondarily from the unnucleated monera. Hence, I made a very thorough study of these rudimentary organisms in my *Monograph on the Monera* (1870), and endeavoured to formulate it more clearly later on (in the first volume of the *Systematic Phylogeny*). In regard to the chemical question of the first formation of plasm and its inorganic preparation, Edward Pflüger conducted some valuable investigations, and recognised that the radical of cyanogen was the chief element of the living plasm. I may therefore distinguish two different stages of the theory—my own older autogony-hypothesis and the later cyanogen-hypothesis.

The theory of abiogenesis, or archigony, which I advanced in 1866, and have developed in later writings,

appeals directly to the biochemical facts that modern vegetal physiology has firmly established. The chief of these facts is that even the living green plant-cell has the synthetic faculty of plasmodomism or carbon-assimilation; that is to say, it is able to build up, by a chemical synthesis and reduction, from simple inorganic compounds (water, carbonic acid, nitric acid, and ammonia), the complex albuminous compounds which we call plasm or protoplasm, and which we regard as the active living substance and the true material basis of all vital function (*cf.* chap. vi.). All botanists are now agreed that this most important process of vegetal life, the fundamental process of all organic life and all organisation, is a purely chemical (or, in the wider sense, physical) process, and that there is no question of a specific vital force or a mystic constructor (like the famous "mechanical engineer of life"), or any other transcendental agency, in connection with it. The tiny chemical laboratory in which this remarkable organoplastic process takes place under the influence of sunlight is, in the simplest plants, the chromacea, either the whole homogeneous globule of plasm (*chroococcus*) or its bluish-green surface-layer, which is active as a chromatic principle (chromatophore). But in most plants these reduction-laboratories are the chromatella or chromatophora, which have been differentiated from the rest of the plasm of the cell, and are colourless globular leucoplasts within its dark interior, or green chromoplasts (or granules of chlorophyll) at its illumined surface. My theory of archigony only assumes that this chemical process of plasmodomism which we find repeated every second in every plant-cell exposed to the sun-light, and which has become an "inherited habit" of the green plant-cell, developed of itself at the

beginning of organic life; in other words, it is a catalytic process (or one analogous to catalysis), the physical and chemical conditions of which were present in the condition of organic nature at that time.

My hypothesis was very strongly confirmed twenty years ago by the adhesion of the able botanist, Carl Naegeli. In his instructive work, *A Mechanical-physiological Theory of Evolution* (1884), he supported all the principal ideas as to the natural origin of life which I had advanced in 1866. He formulates the chief part of them in this admirable principle :—

> The origin of the organic from the inorganic is, in the first place, not a question of experience and experiment, but a fact deduced from the law of the constancy of matter and force. If all things in the material world are causally related, if all phenomena proceed on natural principles, organisms, which are formed of and decay into the same matter, must have been derived originally from inorganic compounds.

This excellent and clear declaration of a distinguished scientist and profound thinker might be taken to heart by the "exact" scientists who are always attacking the monistic theory of archigony as an unproved hypothesis, or regard the whole problem as insoluble. Naegeli has, moreover, proceeded to make a thorough study of the molecular processes involved, and embodied the results in his idioplasm theory. He believes that at the beginning of organisation the definite autonomous arrangement of the smallest homogeneous parts of the plasm was a matter of the greatest importance. In his opinion these "micella" are crystalline groups of molecules, arranged multifariously in strings and parallel rows.

A similar and more elaborate attempt to give a physical explanation of the processes of archigony and trace them to mechanical molecular structures was made by Ludwig

Zehnder in 1899 in his work on *The Origin of Life*. He believes that the smallest and lowest life-unities (the micellar strings of Naegeli and the biophora of Weismann, corresponding to my plastidules) have a tubular shape, and so he calls them "fistella." He supposes that these invisible molecular structures are regularly arranged in millions in the plasma of the cell, and differentiated in such a way that some will effect endosmosis, others contraction, others the conduction of stimuli, and so on. As in the similar work of Naegeli and others, the value of this molecular hypothesis is that it stimulates us to attempt to conceive the mode of the arrangement and movement of the molecules of plasm in the process of archigony on physical principles.

A more interesting and notable attempt to penetrate into the mysterious obscurity of the chemical processes in archigony was made in 1875 by the distinguished physiologist, Eduard Pflüger, in his essay on *Physiological Combustion in the Living Organism*. He starts from the fact that the plasm (or protoplasm) is the material basis of all vital phenomena, and that this living matter owes its properties to the chemical properties of the albumin (whether we regard this as a chemical unity, protein or protalbumin, or as a mixture of different compounds). However, Pflüger sharply distinguishes between the living albumin of the plasm out of which all organisms are built, and the dead albumin, such as we find it, for instance, in the glairy albumin of the hen's egg. Only the living albumin (plasm) decomposes of itself in a slight degree, and to a greater extent under the influence of external excitation; the dead albumin will remain intact for a long time under favourable conditions. The cause of the extraordinary instability of the living albumin is its

intramolecular oxygen—that is to say, the oxygen that is taken into the interior of the plasma-molecules in breathing, and effects there a disassociation, surrounding the atoms and breaking up the new-formed groups.

The real cause of this rapid decomposibility of the plasm, and of the accompanying formation of carbonic acid, is found in the cyanogen, a remarkable body composed of an atom of carbon and an atom of nitrogen, which, in conjunction with potassium, forms the well-known and very virulent poison, cyanide of potassium. The non-nitrogenous decomposition-products of the dead and the living albumin agree in the main, but their nitrogenous products are totally different. Uric acid, creotin, guanine, and the other decomposition products of plasm contain the cyanogen-radical, and the most important of all, urea, can be artificially produced from cyanic compounds, as Wöhler showed in 1828. From this we may infer that the living albumin always contains the cyanogen-radical, and that dead nutritive albumin does not. The belief that it is cyanogen which gives its characteristic vital properties to the plasm is supported by a number of analogies that we find to exist between cyanide compounds, especially cyanic acid (C N O H.) and the living albumin. Both bodies are fluid and transparent at a low temperature, while they set at a higher; both of them break up in the presence of water into carbonic acid and ammonia; both produce urea by disassociation (by the intramolecular surrounding of the atoms, not by direct oxydation). "The similarity of the two substances is so great," says Pflüger, "that I might describe cyanic acid as a semi-living molecule." Both substances grow in the same way by concatenation of the atoms, homogeneous groups of atoms joining together chain-wise in large masses.

There is an especial interest in connection with the theory of archigony and its physical basis in the chemical fact that cyanogen and its compounds—cyanide of potassium, cyanic acid, cyanide of hydrogen, etc.—are only formed at incandescent heat; that is to say, when the requisite inorganic nitrogenous compounds are put with glowing coals, or the mixture is heated to incandescence. Other essential constituents of albumin, such as carburetted hydrogen or alcohol-radical, can be formed synthetically in heat. "Thus," says Pflüger, "nothing is clearer than the possibility of the formation of cyanic compounds when the earth was entirely or partially in a state of incandescence or great heat. We see how extraordinarily all the facts of chemistry point to fire as the force that has produced the constituents of albumin by synthesis. Hence life was born from fire, and the chief conditions of its appearance are associated with a time when the earth was a glowing ball of fire. When we remember the incalculably long period in which the surface of the earth was slowly cooling, we see that cyanogen, and the compounds that contained cyanogen, and carburetted hydrogen, had plenty of time and opportunity to follow out to any extent their great tendency to the transposition and formation of polymeria (chains of atoms), and, with the co-operation of oxygen and afterwards of water and salts, to evolve into the self-decomposable albumin which is living matter." In regard to the latter feature, it is well to emphasise the fact that, as will be understood, there must have been a long series of chemical intermediary stages between the incandescent formation of cyanogen and the appearance of the aqueous living plasm.

Pflüger's cyanogen-theory does not conflict with my monera-theory, but rather supplements it, by its careful

and thoroughly scientific study of a much earlier stage of primitive biogenesis—in a sense, the first period of preparation for the formation of albumin. This must be well borne in mind in view of the attacks which have lately been made on it by Neumeister and other vitalists; it is supposed to be untenable, because "there is an impassable gulf between cyanic compounds and proteids." This criticism is answered by the living albumin itself, which always contains in its nitrogenous decomposition-products the radical of cyanide or other substances (urea) that can be artificially produced from cyanic compounds. Another objection is that "the cyanic compounds which were formed in the heat must have very quickly perished on the subsequent appearance of water." The objection has no weight, since we can form no definite idea as to the special conditions of chemical activity in those times. We can only say that the conditions during this long period (embracing millions of years) were totally different from those of chemical action at the surface of the earth to-day. The real ground of the opposition of Neumeister and other vitalists is their dualistic conception of nature, which will maintain at all costs the deep gulf between the organic and inorganic worlds.

Max Verworn, in his *General Physiology*, has fully described and criticised the various theories of the appearance of life on the earth. He rightly attributes a great value to Pflüger's cyanogen theory, because "it makes a strictly scientific study of the problem in close relation to the facts of physiological chemistry, and goes thoroughly into detail." He agrees with Pflüger when he expresses himself as follows: "I would say, therefore, that the first albumin to be formed was in point of fact living matter, endued with the property in all its radicals

of attracting especially homogeneous parts with great force and preference, in order to build them chemically into the molecule, and so grow indefinitely. On this view the living albumin need not have a constant molecular weight, because it is a huge molecule in an unceasing process of formation and decomposition, probably acting on the ordinary chemical molecules as a sun does on a small meteor." This theory, which I believe to be correct, is also maintained by many other modern scientists who have made a particular study of the difficult question of the nature and origin of the albuminoids.

Now that we have described the various modern theories of archigony that are worth considering, and recognised with Naegeli that the original development of the organic from the inorganic is a fact, we may glance at the older theories which, under the name of "spontaneous generation," afforded matter for a good deal of controversy. It is true that they are now almost entirely abandoned, but the experiments in connection with them excited a good deal of interest and led to many misunderstandings.

The older hypotheses of "spontaneous generation" do not bear on our problem of archigony (or the first development of living matter from lifeless inorganic carbon-compounds), but relate to the formation of lower organisms out of the putrid and decomposing organic elements of higher organisms. In order to distinguish these hypotheses from the totally different theory of archigony, it is better to give them the name of saprobiosis (an earlier name was necrobiosis), which means the birth of living from dead [*nekron*] or putrid [*sapron*] organic matter. Saprobiosis is preferable, because necrobiosis is better used in a different sense, for

the dead organic parts which gradually bring about the death of the living body (see p. 110). It was believed in ancient times that lower organisms could arise from the dead remains of higher organisms, such as fleas from manure, lice from morbid pustules in the skin, moths from old furs, and mussels from slime in the water. As these stories were supported by the authority of Aristotle, and on that account believed by St. Augustine and other fathers, and reconciled with the faith, they were held until the beginning of the eighteenth century. Even in the year 1713 the botanist Heucherus stated that the green duck-weed (*lemna*) is only condensed grease from the surface of foul standing water, and that water-cress was formed from it in fresh running water.

The first scientific refutation of these old stories was made by the Italian physician, Francisco Redi, in 1674, on the basis of very careful experiment: he was persecuted for "unbelief" on that account. He showed that all these animals arose from eggs that had been deposited by female animals in dung, skin, fur, slime, etc. But at that time the proof could not be extended to the tape-worms, maw-worms, and other intestinal animals (*entozoa*), which live inside other animals (in the bowels, blood, brain, or liver). It was still believed that these arise from diseased parts of the host-animals in which they live until about the middle of the nineteenth century. It was not until 1840–1860 that it was shown by the experiments of Siebold, Leuckart, van Beneden, Virchow, and other famous biologists, that all these intestinal animals have come from without into the animals they live in, and propagate there by eggs. Of late years the proof has been applied all round.

On the other hand, the hypothesis of saprobiosis retained its position until quite recently for one section

of the smallest and lowest organisms, the microscopic forms of life, invisible to the naked eye, which were formerly called infusoria, and which we now call by the wider name of protists or unicellulars. When Leewenhoek discovered the infusoria in 1675 with the newly invented microscope, and showed that they arise in great quantities in infusions of hay, moss, flesh, and other putrid organic substances, it was generally believed that they were spontaneously generated there. The abbé Spallanzani showed in 1687 that no infusoria appear in these infusions if they are well boiled and the vessel is carefully closed; the boiling kills the germs in them, and the exclusion of air prevents the entrance of fresh germs. In spite of this, many microscopists still believed that certain infusoria, particularly the very small and simple bacteria, could be born directly from putrid or diseased tissues of organisms, or from decomposing organic fluids; the opinion was maintained by Pouchet at Paris in 1858, and afterwards by Charlton Bastian. The controversy about the subject moved the Paris Academy in 1858 to offer a prize for "careful research that would throw new light on the question of spontaneous generation." It fell to the famous Louis Pasteur, who proved, by a series of ingenious experiments, that there are everywhere in the atmosphere numbers of germs of microbes or microscopic organisms floating among the dust-particles, and that these grow and reproduce when they reach water. Not only infusoria, but also small highly organised plants and animals—such as lichens, mosses, rotifers, and tardigrades—can live for months in a desiccated condition, be carried in all directions by the wind, and re-awaken into life when they reach water. On the other hand, Pasteur showed convincingly that organisms never appear in

infusions of organic substances when they are sufficiently boiled and the atmosphere that reaches them has been chemically purified. He summed up the results of his rigorous experiments, which were confirmed by Robert Koch and other bacteriologists, and gave rise to the modern precautions as to disinfection, in the maxim: "Spontaneous or equivocal generation is a myth."

The famous experiments of Pasteur and his successors had destroyed the myth of saprobiosis, but not the theory of archigony. These entirely different hypotheses are still very frequently confused, because the old title of "spontaneous generation" is used for both. We still read sometimes that the "unscientific" belief in abiogenesis has been definitively refuted by these experiments, and that the question of the origin of life has thus become an insoluble enigma. There is an astonishing superficiality and lack of discernment in such remarks; they would hardly be possible in any other branch of science. But in biology—many of its distinguished representatives continue to say—we have only to observe and correctly describe facts; the formation of clear ideas and the indulgence in reflection on the facts are unnecessary and dangerous, and, therefore, to be avoided! It is due to this pitiable condition of biological methods of research that our hypothesis of archigony is still attacked, or else ignored. Why? Because the false hypothesis of saprobiosis, which has absolutely nothing in common with it but the name "spontaneous generation," has been refuted by the experiments of Pasteur and his colleagues![1] These

[1] [I may remind the English reader that the chosen ecclesiastical champion against Haeckel in this country, the Rev. F. Ballard, made this extraordinary fallacy the very pith of his "scientific" attack on Monism.—TRANS.]

experiments prove nothing whatever beyond the fact that new organisms are not formed in certain infusions of organic matter—under definite, artificial conditions. They do not even touch the important and pressing question, which alone interests us: "How did the earliest organic inhabitants of our earth, the primitive organisms, arise from inorganic compounds?"

The great popularity of the famous experiments of Pasteur on spontaneous generation, and the unfortunate confusion of ideas which was caused by the false interpretation of his results, make it necessary for me to say a word on the general value of scientific experiments in many questions. Since Bacon introduced experiment into science three hundred years ago, and gave it a logical basis, both our speculative knowledge of nature and the practical application of our knowledge made remarkable progress. New methods of research made it possible for modern workers to penetrate far more deeply into the nature of phenomena than the older thinkers had done, who had no knowledge of experiment. Especially in the nineteenth century the development of the experimental method, or the putting of a question to nature, led to enormous advances in the various sciences.

In the subject we are considering the question to be put to nature is: "Under what conditions and in what manner is living matter (or plasm) formed from lifeless inorganic compounds?" We may confidently assume that in the period when archigony took place—the time when organic life first appeared on the cooled surface of the earth, at the beginning of the Laurentian age—the conditions of existence were totally different from what they are now; but we are very far from having a clear idea of what they were, or from being able to reproduce them artificially. We are just as far from

having a thorough chemical acquaintance with the albuminous compounds to which plasm belongs. We can only assume that the plasma-molecule is extremely large, and made up of more than a thousand atoms, and that the arrangement and connection of the atoms in the molecule are very complicated and unstable. But of the real features of this intricate structure we have as yet no conception. As long as we are ignorant of this complex molecular structure of albumin, it is useless to attempt to produce it artificially. Yet in this position of the matter we would seek to produce that great wonder of life, the plasm, artificially, and when the experiment miscarries (as we should expect) we cry out: "Spontaneous generation is impossible."

When we carefully consider the intelligent experiments that have been made in regard to archigony in the light of these facts, it is clear that their negative result does not in the slightest degree affect our question. The much-admired experiments of Pasteur and his colleagues prove merely that in certain artificial conditions infusoria are not formed in decomposing organic compounds (or the dead tissues of highly organised histona); they cannot possibly prove that saprobioses of this kind do not take place under other conditions. They tell us nothing whatever about the possibility or reality of archigony; in the form in which I put the scientific hypothesis in 1866 it is completely untouched by all these experiments. It remains intact as the first attempt to give a provisional reply—if only in the form of a temporary hypothesis—on the basis of modern science to one of the chief questions of natural philosophy.

In my *General Morphology* (1866), and afterwards in my *Biological Studies on the Monera and other Protists*, and the first volume of my *Systematic Phylogeny* (1894),

I attempted to sketch in detail the stages of the process to which I give the name of archigony. I distinguished two principal stages—*autogony* (the formation of the first living matter from inorganic nitrogenous carbon-compounds) and *plasmogony* (the formation of the first individualised plasm; the earliest organic individuals in the form of monera). In more recent efforts I have made use of the important results reached by Naegeli (1884) in his investigations of the same subject. In regard to some important points relating to the chemico-physical part of the question, Naegeli has, in his *Mechanico-physiological Theory of Evolution* (chap. ii.), gone more into the details of the process of archigony. To the earliest living things, which were formed by "unicellular-organisation" of the plasm out of simple inorganic compounds, he gives the name of *probia* or *probionta*, and thinks that these had an even simpler structure than my monera. This view seems to rest on a misunderstanding. Naegeli does not strictly follow my definition, "organisms without organs" (that is to say, structureless living particles of plasm without morphological differentiation), but he has in mind the individual rhizopod-like organisms which I had at first described as monera—*protamœba*, *protogenes*, *protomyxa*, etc. In my present view the chromacea, or plasmodomous phyto-monera, are much more important than these plasmophagous zoomonera. It is curious that Naegeli does not make thorough use of their primitive organisation for the establishment of his theory, although he has had the great merit of describing these most primitive of all living organisms as unicellular algæ (1842). As a matter of fact, the simplest chromacea (chroococcus and related forms) approach so closely to his hypothetical probia or probionta that the only things we can regard as the

rudiments of organisation in the chroococcacea are the secretion of a protective membrane about the homogeneous plasma-globule and the separation of the blueish-green cortical zone from the colourless central granule. The more important of the further conclusions of Naegeli are those which relate to the mode of the primitive abiogenesis and the frequent repetition of this physical process.

Recently Max Kassowitz, in the second volume of his *General Biology* (1899), has gone fully into the various stages of the process of archigony, as a sequel to his metabolic theory of the building-up and decay of plasm, from the point of view of physiological chemistry. He says very truly that the development of living from lifeless matter must not be conceived as a sudden leap; the very complicated chemical unities which now form the basis of life have been slowly and gradually evolved during an incalculably long period by the way of substitution for simpler compounds. We may join these views —which generally accord with my earlier deductions— with Pflüger's cyanogen theory, and so draw up the following theses:—

1. A preliminary stage to archigony is the formation of certain nitrogenous carbon-compounds which may be classed in the cyanic group (cyanic acid, etc.). 2. When the crust of the earth stiffened water was formed in the fluid condition; under its influence, and in consequence of the great changes in the carbonic-acid laden atmosphere, a series of complicated nitrogenous carbon-compounds were formed from these simple cyanic compounds, and these first produced albumin (or protein). 3. The molecules of albumin arranged themselves in a certain way, according to their unstable chemical attractions, in larger groups of molecules (pleona or

micella). 4. The albumin-micella combined to form larger aggregations, and produced homogeneous plasma-granules (plassonella). 5. As they grew the plassonella divided, and formed larger plasma-granules of a homogeneous character: monera ( = probionta). 6. In consequence of surface-strain or of chemical differentiation, there took place a separation of the firmer cortical layer (membrane) from the softer marrow-layer (central granule), as in many of the chromacea. 7. Afterwards the simplest (nucleated) cells were formed from these unnucleated cytodes, the hereditary mass of the plasm gathering within the monera and condensing into a firm nucleus.

It is an interesting, but at present unanswered, question whether the process of archigony only occurred once in the course of time or was frequently repeated. Reasons can be given for both views. Pflüger says: "In the plant the living albumin only continues to do what it has done ever since its origin—constantly to regenerate itself or to grow; hence I believe that all the albumin in the world comes from that source. On that account I doubt if spontaneous generation takes place in our time. Moreover, comparative biology directly shows that all life has come from one single root." However, this view does not exclude the possibility of the chemical process of spontaneous plasmodomism having been frequently repeated—under like conditions—in the same form in primordial times.

On the other side, Naegeli especially has pointed out that there is no reason to prevent us from thinking that archigony was repeated several times, even down to our own day. Whenever the physical conditions for the chemical process of plasmodomism were given, it might be repeated anywhere at any time. As to locality, the

sea-shore probably affords the most favourable conditions; as, for instance, on the surface of fine moist sand the molecular forces of matter in all its conditions—gaseous, fluid, viscous, and solid—find the best conditions for acting on each other. It is a fact that to-day all the various evolutionary forms of living matter—from the simplest moneron (chroococcus) to the plain nucleated cell, from this to the highly-organised cell of the radiolaria and infusoria, from the simple ovum to the most elaborate tissue-structure in the higher plants and animals, from the amphioxus to man—come in an order of succession. There are only two ways of explaining this fact: either the simplest living organisms, the chromacea and bacteria, the palmella and amœbæ, have remained unchanged or made very little advance in organisation since the beginning of life—more than a hundred million years; or else the phylogenetic process of their transformation has been frequently repeated in the course of this period, and is being repeated to-day. Even if the latter were the case, we should hardly be in a position to learn it by direct observation.

Assuming that the simplest organisms are still formed by abiogenesis, the direct observation of the process would probably be impossible, or at least extremely difficult, for the following reasons: 1. The earliest and simplest organisms are most probably globular particles of plasm, without any visible structure, like the simplest living chromacea *(chroococcus)*. 2. These plasmodomous monera cannot be distinguished from the chromoplasts (chlorophyll-granules), which live inside plant-cells, and may continue after the death of the cells to multiply independently by cleavage. 3. We must admit with Naegeli that the original size of these probionta (in spite of the relatively colossal size of their

molecules) is very small—much too small to come within the range of the best microscope. 4. In the same way the primitive metabolism and the slow, simple growth of these monera would not come within direct observation. 5. As a matter of fact, we do often find in stagnant water, and in the sea, tiny granules which consist, or seem to consist, of plasm. We usually regard them as detached portions of dead animals or plants; little isolated chlorophyll-granules that may be found everywhere are looked upon as rejected products of vegetal cells. But who could refute the assumption that they are really plassonella or young monera, which grow slowly and unite with similar particles to form larger plasmic bodies?

It is often objected to our naturalistic and monistic conception of archigony that we have not yet succeeded in forming albuminous bodies, and especially plasm, in our chemical laboratories by artificial synthesis; from this the perverse dualistic conclusion is drawn that it is only supernatural vital forces that can do this. It is forgotten that we do not yet know the complicated structure of albuminous bodies, and that we do not yet know what really happens inside the green chlorophyll-granules which in every plant-cell convert the radiant energy of sun-light into the virtual energy of the new-formed plasm. How can we be expected to reproduce synthetically, with the imperfect and crude methods of present chemistry, an elaborate chemical process the nature of which is not analytically known to us? However, the worthlessness of this sceptical objection is obvious: we can never claim that a natural process is supernatural because we cannot artificially reproduce it.

## Chapter XVI.

# THE EVOLUTION OF LIFE

Inorganic and organic evolution. Biogenesis and cosmogenesis. Mechanical evolution. Mechanics of phylogenesis. Theory of selection. Theory of idioplasm. Phyletic vital force. Theory of germplasm. Progressive heredity. Comparative morphology. Germplasm and hereditary matter. Theory of mutation. Zoological and botanical transformism. Neolamarckism and Neodarwinism. Mechanics of ontogenesis. Biogenetic law. Tectogenetic ontogeny. Experimental evolution. Monism and biogeny.

I FULLY explained in my *General Morphology* (1866) the profound importance of the science of evolution in relation to our monistic philosophy. A popular synopsis of this is given in my *History of Creation*, and is briefly repeated in the thirteenth chapter of the *Riddle*. I must refer the reader to these works, especially the latter, and confine myself here to a consideration of some of the principal general questions of evolution in the light of modern science. The first thing to do is to compare the conflicting views on the nature and significance of biogenesis which still face each other at the beginning of the twentieth century.

The essential unity of inorganic and organic nature, which I endeavoured to establish in the second book of the *General Morphology*, and the significance of which I explained in the fourteenth chapter of the *Riddle*, is found through the whole course of its development, in the causes of phenomena and their laws. Hence, in dealing with the evolution of organisms, we reject

vitalism and dualism, and maintain our conviction that it can always be traced to physical forces (and especially chemical energy). As we regard plasm as the basis of it (chap. vi.), we may say that organic evolution depends on the mechanics and chemistry of the plasm. We postulate no supernatural vital force for the explanation of physiological functions, and we are just as far from admitting it as regulator or agency of the biogenetic process.

If we understand by biogeny the sum-total of the organic evolutionary processes on our planet, by geogeny the processes at work in the formation of the earth itself, and by cosmogony those that produced the whole world, biogeny is clearly only a small part of geogeny, and this in turn only a small section of the vast science of cosmogony. This important relation is evident enough, yet often overlooked; it holds both of time and space. Even if we suppose that the biogenetic process occupied more than a hundred million years, this period is probably much shorter than that which our planet has needed for its development as a cosmic body—from the first detachment of the nebular ring from the shrinking body of the sun to its condensation into a rotating sphere of gas, and from this to the formation of the incandescent globe, the stiffening of the crust at its surface, and finally the downpour of fluid water. It was not until this last stage that carbon could begin its organogenetic activity and proceed to the formation of plasm. But even this long geogenetic process is, as regards space and time, only a very small part of the illimitable history of the world. If we further assume that organic life developes on other cosmic bodies (*Riddle*, chap. xx.) in the same way as on our earth under like conditions, the whole sum of all these biogenetic processes is only a small part of the all-embracing

cosmogenetic process. The vitalistic belief that its mechanical course was interrupted from time to time by the supernatural creation of organisms is opposed to pure reason, the unity of nature, and the law of substance. We must, therefore, hold fast above all to the conviction that all biogenetic processes are just as reducible to the mechanics of substance as all other natural phenomena.

The mechanical and natural character of the development of inorganic nature, the earth and the whole material world, was established mathematically at the end of the eighteenth century by the great atheist Laplace in his *Mécanique Céleste* (1799). The similar cosmogony which Kant had expounded in 1755 in his *General Natural History and Theory of the Heavens* only obtained recognition at a later date (*Riddle*, chap. xiii.). But the possibility of giving a mechanical explanation of organic nature was not seen until Darwin provided a solid foundation for the theory of descent by his theory of selection in 1859. I made the first comprehensive attempt to do this in 1866 in my *General Morphology*, the aim of which is expressed in the title: "General outlines of the science of organic forms, mechanically grounded on Darwin's improvement of the theory of descent." Especially in the second volume of the work, the "General Evolution of Organisms," I endeavoured to show that both sections of the science, ontogeny (or embryology) and phylogeny, can be reduced to physiological activities of the plasm, and so explained mechanically, in the wider meaning of the word.

When I stated the nature and the aim of phylogeny in 1866, most biologists regarded my attempt as unjustifiable, as they did Darwinism itself, of which it was a natural consequence. Even the famous Emil du Bois-Reymond, to whom as a physiologist it should have

been welcome, described it as "a poor romance"; he compared my first attempts to construct the genealogical tree of the organic classes, on the evidence of paleontology, comparative anatomy, and ontogeny, to the hypothetical labours of philologists to draw up the genealogical tree of the legendary Homeric heroes. As a matter of fact, I had myself described my imperfect effort as merely a provisional sketch, as a temporary hypothesis that would open the way for later and better research. A single glance at the immense literature of phylogeny to-day shows how much has been done since in this province, and how far we have advanced in the establishment of the features of evolution by means of the united labours of numbers of able paleontologists, anatomists, and embryologists. Ten years ago I attempted, in the three volumes of my *Systematic Phylogeny*, to give a comprehensive statement of the results attained. My chief aim was, on the one hand, to construct a natural system of organisms on the basis of their ancestral history, and on the other hand to prove the mechanical character of the phylogenetic process. All the activities of organisms which are at work in the transformation of species and the production of new ones in the struggle for existence may be reduced to their physiological functions—to growth, nutrition, adaptation, and heredity; and these again to the mechanics and chemistry of the plasm. The struggle for life is itself a mechanical process, in which natural selection uses the disproportion between the excess of germs and the restricted means of existence, in conjunction with the variability of species, in order to produce new purposive structures mechanically and without any preconceived design. This teleological mechanicism has no need of a mysterious design or finality; it takes its place in the

general order of mechanical causality which controls all the processes in the universe. Natural finality is only a special instance of mechanical causality. The one is subordinate to the other, not opposed to it, as Kant would have it.

The effort that the great Lamarck made in 1809, in his *Philosophie Zoologique*, to establish transformism deserves high appreciation from Monists, because it was the first attempt to give a natural explanation of the origin of the countless species of organic forms which inhabit our planet. Up to that time it had been the fashion to attribute their origin to a miraculous intervention of the Creator. This metaphysical creationism had now to face physical evolutionism. Lamarck explained the gradual formation of organic species by the interaction of two physiological functions—adaptation and heredity. Adaptation consists in the improvement of organs by use, and degeneration by disuse; heredity acts by transmitting the features thus acquired to posterity. New species arise by physiological transformation from older species. The fact that this great thought was overlooked for half a century does not detract from its profound significance. But it only obtained general recognition when Darwin had supplemented it and filled up its causal gaps by the theory of selection in 1859. Apart from this specifically Darwinian feature (whether it be true or not), the fundamental idea of transformism is now generally received; it is admitted to-day even by metaphysicians who maintained a spirited opposition to it thirty years ago. The fact of the progressive modification of species is only intelligible on Lamarck's theory, that the actual species are the transformed descendants of older species. In spite of all the learning and zeal with which the theory has been

attacked, it has proved irrefutable; nor can any one suggest a better theory to replace it. This may be said particularly of its chief consequence—the descent of man from a series of other mammals (proximately from the apes).

The high value of Darwin's theory of selection for the monistic biology is now acknowledged by all competent and impartial authorities on the science. In the course of the forty-four years since it found its way into every branch of biology, it has been employed in more than a hundred large works and several thousand essays in explaining biological phenomena. This alone is enough to show its profound importance. Hence it is mere ignorance of the subject and its literature to say, as has been done several times of late, that Darwinism is in decay, or even "dead and buried." However, absurd writings of this kind (such as Dennert's *At the Death-bed of Darwinism*) have a certain practical influence, because they fall in with the prevailing superstition in theology and metaphysics. Unfortunately, they also seem to obtain notice from the circumstance that a few botanists persistently attack the Darwinian theory. One of the most conspicuous of these is Hans Driesch, who affirms that all Darwinists (and therefore the great majority of modern biologists) have softening of the brain, and that Darwinism is (like Hegel's philosophy) the delusion of a generation. The arrogance of this conceited writer is about equal to the obscurity of his biological opinions, the confusion of which is covered by a series of most extravagant metaphysical speculations. All these attacks have lately been met very ably by Plate in his work, *On the Significance of the Darwinian Principle of Selection and the Problem of the Foundation of Species* (2nd ed., 1903). The most thorough of recent defences of Darwinism is that made

by August Weismann in his *Lectures on the Theory of Descent* (1902) and other works. But the distinguished zoologist goes too far when he seeks to prove the omnipotence of selection and wishes to ground it on an untenable molecular hypothesis—the theory of germplasm, which we will consider presently. Apart from these or other exaggerations, we may say with Weismann that Lamarck's theory of descent received a sound causal basis by Darwin's theory of selection. Its real foundations are these three phenomena: heredity, adaptation, and the struggle for existence. All three are, as I have often said, of a purely mechanical and not a teleological nature. Heredity is closely bound up with the physiological function of reproduction, and adaptation with nutrition; the struggle for life follows logically and mathematically from the disproportion between the number of potential individuals (germs) and of actual individuals that grow to maturity and propagate the species.

When I had, in my *General Morphology*, endeavoured to gain acceptance for Darwin's theory of selection, and had presented evolution as a comprehensive theory from the point of view of the monistic philosophy, a number of works, sometimes of value, appeared, which made special studies of the various parts of the immense province. Eighteen years afterwards a greater work was published, which started from the same monistic principles, but reached the same conclusion by a different way. In 1884 Carl Naegeli, one of our ablest and most philosophic botanists, issued his *Mechanical-physiological Theory of Evolution*. This interesting book consists of various parts. It is especially notable that evolution is presented in it as the one possible and natural theory of the origin of species; even morphology and classification are treated

explicitly as "phylogenetic sciences." The chapter on archigony—a dark and dangerous problem that is generally avoided by scientists!—is one of the best that has been written on the subject. On the other hand, Naegeli rejects Darwin's theory of selection altogether, and would explain the origin of species by an inner "definitely directed variation," independently of the conditions of existence in the outer world. As Weismann has properly observed, this internal principle of evolution, which dispenses with adaptation in the true sense of the word, is at the bottom merely a "phyletic vital force." It is not made more acceptable by Naegeli when he builds up a subtle metaphysical system on it and postulates a special "principle of isagitation." But the idioplasm theory he connects with it is of some value, since it goes more fully into the differentiation of the cell-plasm into two physiologically different parts—the idioplasm of the hereditary matter and the trophoplasm as nutritive matter of the cell.

The vitalist and teleological idea of an internal principle of evolution, that determines the origin of animal and plant species independently of the environment and its conditions, is not only found in the "mechanical-physiological" theory of Naegeli, but also in several other attempts to explain the agencies of the transformation of species. All these efforts are welcomed by the academic philosophers with their Kantist dualism (mechanicism on the right, teleology on the left), and who are particularly anxious to save the supernatural element, Reinke's "cosmic intelligence," or the wisdom of the creator, or the divine creative thought. All these dualistic and teleological efforts have the same fault: they overlook, or fail to appreciate properly, the immense influence of the environment on the shaping and

modification of organisms. When, moreover, they deny progressive heredity and its connection with functional adaptation, they lose the chief factor in transformation. This applies also to the theory of germ-plasm.

The desire to penetrate deeper into the mysterious processes that take place in the plasm in the physiological activities of heredity and adaptation has led to the formulation of a number of molecular theories. The chief of these are the pangenesis theory of Darwin (1878), my own perigenesis theory (1876), the idioplasm theory of Naegeli (1884), the germ-plasm theory of Weismann (1885), the mutation theory of de Bries, etc. As I have already dealt with these in the sixth chapter (as well as in the ninth chapter of the *History of Creation*), I may refer the reader thereto. None of these or similar attempts has completely solved the very difficult problems in question, and none of them has been generally received. There is, however, one of them that we must consider more closely, because it is not only regarded by many biologists as the greatest advance of the theory of selection since Darwin, but it also touches the roots of several of the chief problems of biogeny. I mean the much-discussed germ-plasm theory of August Weismann (of Freiburg), one of our most distinguished zoologists. He has not only promoted the theory of descent by his many writings during the last thirty years, but has also put in its proper light the great importance and entire accuracy of the theory of selection. But, in his efforts to provide a molecular-physiological basis for it, he has proceeded by way of metaphysical speculation to frame a quite untenable theory of the plasm. While fully recognising the ability and consistency and the able treatment which Weismann has shown, I am compelled once more to dissent from him. His ideas have recently been completely refuted by Max

Kassowitz (1902) in his *General Biology*, and Ludwig Plate in the work I mentioned on the Darwinian principle of selection. We need not go into the details of the complicated hypothesis as to the molecular structure of the plasm which Weismann has framed in support of his theory of heredity—his theory of biophora, determinants, ideas, etc.—because they have no theoretical basis and are of no practical use. But we must pass some criticism on one of their chief consequences. In the interest of his complicated hypotheses, Weismann denies one of Lamarck's most important principles of transmutation—namely, the inheritance of acquired characters.

When I made the first attempt in 1866 to formulate the phenomena of heredity and adaptation in definite laws and arrange these in series, I drew a distinction between conservative and progressive heredity (chap. ix., *History of Creation*). Conservative heredity, or the inheritance of inherited characters, transmits to posterity the morphological and physiological features which each individual has received from his parents. Progressive heredity, or the inheritance of acquired characters, transmits to offspring a part of those features which were acquired by the parents in the course of their individual lives. The chief of these are the characters that are caused by the activity of the organs themselves. Increase in the use of the organs causes a greater access of nourishment and promotes their growth; decrease in the exercise of organs has the contrary effect. We have examples at hand in the modification of the muscles or the eyes, the action of the hand or throat in painting or singing, and so on. In these and all the arts the rule is: Practice makes perfect. But this applies almost universally to the physiological activity of the plasm,

even its highest and most astounding function—thought; the memory and reasoning capacity of the phronema are improved by constant exercise of the cells which compose this organ, just as we find in the case of the hands and the senses.

Lamarck recognised the great morphological significance of this physiological use of the organs, and did not doubt that the modification caused was transmitted to offspring to a certain extent. When I dealt with this correlation of direct adaptation and progressive heredity in 1866, I laid special stress on the "law of cumulative adaptation" (*General Morphology*, ii., p. 208). "All organisms undergo important and permanent (chemical, morphological, ard physiological) changes when acted on by a change in its life-conditions, slight in itself, but continuing for a long time or being frequently repeated." At the same time I pointed out that in this case two groups of phenomena are closely connected which are often separated—namely, cumulative heredity: firstly *external*, by the action of the external conditions (food, climate, environment, etc.), and secondly *internal*, by the reaction of the organism, the influence of internal conditions (habit, use and disuse of organs, etc.). The action of outer influences (light, heat, electricity, pressure, etc.) not only causes a reaction of the organism affected (energy of movement, sensation, chemosis, etc.), but it has an especial effect as a trophic stimulus on its nutrition and growth. The latter element has been particularly studied by Wilhelm Roux; his functional adaptation (1881) coincides with my cumulative adaptation, the close relation of which to correlative adaptation I had pointed out in 1866. Plate has recently given this "definitely directed variation" the name of ectogenetic orthogenesis, or, briefly, ectogenesis.

The controversy about progressive heredity still continues here and there. Weismann completely denies it, because he cannot bring it into harmony with his germ-plasm theory, and because he thinks there are no experimental proofs in support of it. A number of able biologists agree with him, led away by his brilliant argumentation. However, many of them foolishly lay great stress on experiments in heredity which prove nothing; for instance, the fact that the offspring of a mammal that has had its tail cut off do not inherit the feature. A number of recent observations seem to prove that in a few cases even defects of this sort (when they have caused profound and lasting disease of the part affected) may be transmitted to offspring. However, as far as the formation of new species is concerned the fact is of no consequence; in this it is a question of cumulative or functional adaptation. Experimental proofs of this are difficult to find, if one wants a strict demonstration of the type of physical experiments; the biological conditions are generally too complicated and offer too many weak points to rigorous criticism. The beautiful experiments of Standfuss and C. Fisher (Zürich) have shown that changes in the environment (such as temperature or food) can cause striking modifications that are transmitted to offspring. In any case, there are plenty of luminous proofs of progressive heredity in the vast arsenal of morphology, comparative anatomy, and ontogeny.

Comparative anatomy affords a number of most valuable arguments for other phylogenetic questions as well as progressive heredity; and the same may be said of comparative anatomy and comparative ontogeny. I have collected and illustrated a good many of these proofs in the new edition of my *Anthropogeny*. However,

in order to understand and appreciate them aright, the reader must have some acquaintance with the methods of critical comparison. This means not only an extensive knowledge of anatomy, ontogeny, and classification, but also practice in morphological thinking and reasoning. Many of our modern biologists lack these qualifications, especially those "exact" observers who erroneously imagine they can understand vast groups of phenomena by accurate description of detailed microscopic structures, etc. Many distinguished cytologists, histologists, and embryologists have completely lost the larger view of their work by absorption in these details. They even reject some of the fundamental ideas of comparative anatomy, such as the distinction between homology and analogy; Wilhelm His, for instance, declared that these "academic ideas" are "unreliable tools." On the other hand, physiological experiments ought to contribute to the solution of morphological problems, and of these they can say nothing. To show the incalculable value of comparative anatomy for phylogeny, I need only point to one of its most successful departments, the skeleton of the vertebrates, the comparison of the various forms of the skull, the vertebral column, the limbs, etc. It is not in vain that for more than a hundred years gifted scientists, from Goethe and Cuvier to Huxley and Gegenbaur, have devoted years of laborious research to the methodical comparison of these similar yet dissimilar forms. They have been rewarded by the discovery of the common laws of structure, which can only be explained in the sense of modern evolution by descent from common ancestors.

We have a striking example of this in the limbs of mammals, which, with the same internal skeletal structure, show a very great variety in outer form—the

slender bones of the running carnivora and ungulates, the oar-bones of the whale and seal, the shovel-bones of the mole and hypudæus, the wings of the bat, the climbing bones of the ape, and the differentiated limbs of the human body. All these different skeletal forms have descended from the same common stem-form of the oldest Triassic mammals; their various forms and structures are adapted in scores of ways to different functions; but they rise *through* these functions, and all these functional adaptations can only be understood by progressive heredity. The theory of germ-plasm gives no causal explanation whatever of them.

The majority of recent biologists are of opinion that of the two chief constituents of the nucleated cell the cytoplasm of the cell-body discharges the function of nutrition and adaptation, while the caryoplasm of the nucleus accomplishes reproduction and heredity. I first advanced this view in the ninth chapter of the *General Morphology* (in 1866); and it was afterwards solidly and empirically established by the excellent investigations of Eduard Strasburger, the brothers Oscar and Richard Hertwig, and others. The elaborate finer structures which these observers discovered in cell-division led to the theory that the colourable part of the nucleus, chromatin, is the real hereditary matter, or the material substratum of the energy of heredity. Weismann added the theory that this germ-plasm lives quite separately from the other substances in the cell, and that the latter (the soma-plasm) cannot transmit to the germ-plasm the characters it has acquired by adaptation. It is on the strength of this theory that he opposes progressive heredity. The representatives of the latter (including myself) do not accept this absolute separation of germ-plasm from body-plasm; we believe that even in the

process of cell-division in the unicellular organism there is partial blending of the two kinds of plasm (caryolysis), and that in the multicellular organism of the histona also the harmonious connection of all the cells by their plasma-fibres makes it possible enough for all the cells in the body to act on the germ-plasm of the germ-cells. Max Cassowitz has shown how we can explain this influence by the molecular structure of the plasm.

At the beginning of the twentieth century a new biological theory aroused a good deal of interest, and was welcomed by some as an experimental refutation of Darwin's theory of selection and by others as a valuable supplement to it. The distinguished botanist Hugo de Bries (of Amsterdam) gave an interesting lecture at the scientific congress at Hamburg in 1901 on "The Mutations and Mutation-periods in the Origin of Species." Supported by many years of experiments in selection and some ingenious speculations, he thinks he has discovered a new method of the transformation of species, an abrupt modification of the specific form at a bound, and so discredited Darwin's theory of their gradual change through long periods of time. In a large work on *Experiments and Observations on the Origin of Species in the Plant Kingdom* (1903) de Bries has endeavoured to demonstrate the truth of his theory of mutation. The warm approval which it won from a number of eminent botanists, and especially vegetal physiologists, was not shared by zoologists. Of these Weismann, in his *Lectures on the Theory of Descent* (1902, ii., p. 358), and Plate in his *Problems of Species-formation* (1903, p. 174), have dealt fully with the theory of mutation, and, while appreciating the interesting observations and experiments of de Bries, have rejected the theory he has built on them. As I share their opinion, I may refer the reader

who is interested in these difficult problems to their works, and will restrict myself here to the following observations. The chief weakness of the theory of mutation of de Bries is on its logical side, in his dogmatic distinction between species and variety, mutation and variation. When he holds the constancy of species as a fundamental "fact of observation," we can only say that this (relative) permanence of species is very different in the different classes. In many classes (for instance, insects, birds, many orchids and graminea) we may examine thousands of specimens of a species without finding any individual differences; in other classes (such as sponges, corals, in the genera *rubus* and *hieracium*) the variability is so great that classifiers hesitate to draw up fixed species. The marked difference between various forms of variability which de Bries alleges cannot be carried through; the fluctuating variations (which he takes to be unimportant) cannot be sharply distinguished from the abrupt mutations (from which new species are supposed to result at a bound). De Bries's mutations (which I distinguished in the *General Morphology* as "monstrous changes" from other kinds of variation) must not be confused with the paleontological mutations of Waagen (1869) and Scott (1894) which have the same name. The sudden and striking changes of habit which de Bries observed only in one single species of *œnothera* very rarely occur, and cannot be regarded as common beginnings of the formation of new species. It is a curious freak of chance that this species bears the name *œnothera Lamarckiana;* the views of the great Lamarck on the powerful influence of functional adaptation have not been refuted by de Bries. It must be carefully noted, in fact, that de Bries is firmly convinced of the truth of Lamarck's theory of descent,

like all competent modern biologists. This must be well understood, because recent metaphysicians see in the supposed refutation of Darwinism the death of the whole theory of transformism and evolution. When they appeal in this sense to its most virulent opponents, Dennert, Driesch, and Fleischmann, we may remind them that the curious sermons of these minor sophists are no longer noticed by any competent and informed scientist.

Not only in the brilliant speculations of de Bries and Naegeli, but also in many other botanical works that have lately attempted to advance the theory of descent, we find a striking difference from the prevailing views of zoologists in the treatment of a number of general biological problems. This difference is, of course, not due to a disproportion of ability in the two great and neighbouring camps of biology, but to the differences in the phenomena that we observe in plant life on the one hand and animal life on the other. It must be noted particularly that the organism of the higher animals (including our own) is much more elaborately differentiated in its various organs and much more exposed to our direct experience than that of the higher plants. The chief properties and activities of our muscles, skeleton, nerves, and sense-organs, are understood at once in comparative anatomy and physiology. The study of the corresponding phenomena in the bodies of the higher plants is much more difficult. The features of the innumerable elementary organs in the cell-monarchy of the animal body are much more intricate, yet at the same time much more intelligible, than those of the cell-republic of the higher plant-body. Thus the phylogeny of the plants encounters much greater difficulties than that of the animals; the embryology of the former says much less in detail than that of

the latter. We can understand, therefore, why the biogenetic law is not so generally recognised by botanists as by zoologists. Paleontology, which provides such valuable fossil material for many groups of the animal kingdom that we can more or less correctly draw up their ancestral tree on the strength of this, gives us very little for most groups of the plant kingdom. On the other hand, the large and sharply demarcated plant-cell, with its various organella, is much more valuable in connection with many problems than the tiny animal-cell. For many physiological purposes, in fact, the higher plant body is more accessible to exact physical and chemical research than the higher animal body. The antithesis is less in the kingdom of the protists, as the difference between animal and vegetal life is mostly confined to difference of metabolism, and finally disappear altogether, in the province of the unicellular forms of life. Hence, for a clear and impartial treatment of the great problems of biology, and especially of phylogeny, it is imperative to have a knowledge of both zoological and botanical investigation. The two great founders of the theory of descent—Lamarck and Darwin—were able to penetrate so deeply into the mysteries of organic life and its development because they had extensive attainments both in botany and zoology.

Of the various tendencies that have recently made their appearance among zoologists and botanists in the discussion of the theory of descent, we frequently find Neo-Lamarckism and Neo-Darwinism distinguished as opposing schools. This opposition has no meaning unless we understand by it the alternatives of transformism—with or without the theory of selection. The one principle that distinguishes Darwinism proper from the older Lamarckism is the struggle for existence and

the theory of selection based on it. It is quite wrong to make the test an acceptance or rejection of progressive heredity. Darwin was just as firmly convinced as Lamarck or myself of the great importance of the inheritance of acquired characters, and particularly of the inheritance of functional adaptations; he merely ascribed to it a more restricted sphere of influence than Lamarck. Weismann, however, denies progressive heredity altogether, and wants to trace everything to "the omnipotence of natural selection." If this view of Weismann and the theory of germ-plasm he has based on it are correct, he alone has the honour of founding a totally new (and in his opinion very fruitful) form of transformism. But it is quite wrong to describe this Weismannism as Neo-Darwinism, as frequently happens in England. It is just as wrong to call Naegeli, de Bries, and other modern biologists who reject selection, Neo-Lamarckists.

If the theory of descent is right, as all competent biologists now admit, it puts on morphology the task of assigning approximately the origin of each living form. It must endeavour to explain the actual organisation of each by its past, and to recognise the causes of its modification in the series of its ancestors. I made the first attempt to achieve this difficult task in founding stem-history or phylogeny as an independent historical science in my "General Evolution" (in the second volume of the *General Morphology*). With it I associated as a second and equally sound part ontogeny; I understood by this the whole science of the development of the individual, both embryology and metamorphology. Ontogeny enjoys the privileges (especially in the way of certainty) of a purely descriptive science, when it confines itself to the faithful description of the directly

observed facts, either the embryonic processes in the womb or the later metamorphic processes. The task of phylogeny is much more difficult, as it has to decipher long-past processes by means of imperfect evidence, and has to use its documents with the utmost prudence.

The three most valuable sources of evidence in phylogeny are paleontology, comparative anatomy, and ontogeny. Paleontology seems to be the most reliable source, as it gives us tangible facts in the fossils which bear witness to the succession of species in the long history of organic life. Unfortunately, our knowledge of the fossils is very scanty and often very imperfect. Hence the numerous gaps in its positive evidence have to be filled up by the results of two other sciences, comparative anatomy and ontogeny. I have dealt fully with this in my *Anthropogeny*. As I have also spoken of the general features of these phyletic evidences in the sixteenth chapter of the *History of Creation*, I need do no more here than repeat that it is necessary to make equal and discriminating use of all three classes of documents if we are to attain the aim of phylogeny correctly. Unfortunately, this necessitates a thorough knowledge of all three sciences, and this is very rare. Most embryologists neglect paleontology, most paleontologists embryology, while comparative anatomy, the most difficult part of morphology, involving most extensive knowledge and sound judgment, is neglected by both. Besides these three sources of phylogeny there is valuable proof afforded by every branch of biology, especially by chorology, œcology, physiology, and biochemistry.

Although there has been very extensive phylogenetic research during the last thirty years, and it has yielded a

number of interesting results, many scientists still seem to look on them with a certain distrust; some contest their scientific value altogether, and say that they are nothing but airy and untenable speculations. This is especially the case with many physiologists who look upon experiment as the only exact method of investigation, and many embryologists who think their sole task is description. In view of these sceptical strictures, we may recall the history and the nature of geology. No one now questions the great importance and the various uses of this science, although in it there is no possibility of directly observing the historical processes as a rule. No scientist now doubts that the three vast successive formations of the Mesozoic period—the Triassic, Jurassic, and Cretaceous—have been formed from sea-deposits (lime, sandstone, and clay), though no one was a witness to the actual formation; no one doubts to-day that the fossil skeletons of fishes and reptiles which we find in these groups are not mysterious freaks of nature, but the remains of extinct fishes and reptiles that lived on the earth during those millions of years long ago. And when comparative anatomy shows us the genealogical connection of these related forms, and phylogeny (with the aid of ontogeny) constructs their ancestral trees, their historical hypotheses are just as sound and reliable as those of geology; the only difference is that the latter are much simpler, and thus easier to construct. Phylogeny and geology are, in the nature of the case, *historical sciences.*

Hypotheses are necessary in phylogeny and geology, where the empirical evidence is incomplete, as in every other historical science. It is no detraction from the value of these to urge that they are sometimes weak and have to be replaced by better and stronger ones. A

weak hypothesis is always better than none. We must, therefore, protest against the foolish dread of hypotheses which is urged against our phylogenetic methods by the representatives of the exact and descriptive sciences. This shrinking from hypotheses often hides a defective knowledge of other sciences, an incapacity for synthetic thought, and a feeble sense of causality. The delusions into which it leads many scientists may be seen from the fact that chemistry, for instance, is reckoned an "exact" science; yet no chemist has ever seen the atoms and molecules of compounds with which he is occupied daily, or the complicated relations on the assumption of which the whole of modern structural chemistry is based. All these hypotheses rest on inferences, not on direct observation.

I have, from the first, insisted on the close causal connection between ontogeny and phylogeny, ever since I distinguished these two parts of biogeny in the fifth book of the *General Morphology*. I also laid stress on the mechanical character of these sciences, and endeavoured to give a physiological explanation of their morphological phenomena. Until then embryology had been regarded as a purely descriptive science. Carl Ernst Baer, who had provided a solid foundation for it in his classic *Animal Embryology* (1828), was convinced that all the phenomena of individual development might be reduced to the laws of growth; but he was quite unconscious of the real direction of this growth, its "purposiveness," the real causes of construction. The distinguished Würtzburg anatomist, Albert Kölliker, whose *Manual of Human Embryology* (1859) gave the first comprehensive treatment of the science from the cellular point of view, adhered, even in the fourth edition (1884), to the opinion that "the laws of the

development of the organism are still completely unknown." In opposition to this generally-received opinion, I endeavoured, in 1866, to prove that Darwin had, by his improvement of the theory of descent, not only solved the phylogenetic problem of the origin of species, but, at the same time, given us the key to open the closed doors of embryology, and to learn the causes of the ontogenetic processes as well. I formulated this view in the twentieth chapter of the *General Morphology*, in forty-four theses, of which I will quote only the following three: 1. The development of organisms is a physiological process, depending on mechanical causes, or physico-chemical movements. 40. Ontogenesis, or the development of the organic individual, is directly determined by phylogenesis, or the evolution of the organic stem *(phylon)* to which it belongs. 41. Ontogenesis is a brief and rapid recapitulation of phylogenesis, determined by the physiological functions of heredity and adaptation. The pith of my biogenetic principle is expressed in these and the remaining theses on the causal nexus of biontic and phyletic development. At the same time I make it quite clear that I reduce the physical process of ontogenesis, and also phylogenesis, to a pure mechanics of the plasm (in the sense of the critical philosophy).

The comprehensive fundamental law of organic development was briefly formulated by me in the fifth book of the *General Morphology* and in the tenth chapter of the *History of Creation* (developed more fully in the fourteenth chapter of the tenth edition, 1902). I afterwards sought to establish it securely in two different ways. In the first place, I proved in my *Studies of the Gastræa-Theory* (1872–7) that in all the tissue-animals, from the lowest sponges and polyps to the highest articulata and vertebrates, the multicellular organism

developes from the same primitive embryonic form (the *gastrula*), and that this is the ontogenetic repetition, in virtue of heredity, of a corresponding stem-form (the *gastræa*). In the second place, I made the first attempt in my *Anthropogeny* (1874) to illustrate this recapitulation theory from the instance of our own human organism, by trying to explain the complex process of individual development, for the whole frame and every single part of it, by causal connection with the stem-history of our animal ancestors. In the latest edition of this monistic "ontogeny of man" I gave numbers of illustrations (30 plates and 500 engravings) of these intricate structures, and endeavoured to make the subject still plainer by the addition of sixty genetic tables. I may refer the reader to this work,[1] and not dwell any further here on the biogenetic law, especially as one of my pupils, Heinrich Schmidt (of Jena), has recently described its biological significance and its earlier history and present position in a very clear and reliable little work (*Haeckel's Biogenetic Law and its Critics*). I will only add a word or two on the struggle that has taken place for thirty years over the complete or partial recognition of the biogenetic law, its empirical establishment, and its philosophic application.

In the very name, "Fundamental law of biogeny," which I have given to my recapitulation theory, I claim that it is universal. Every organism, from the unicellular protists to the crytogams and cœlenteria, and from these up to the flowering plants and vertebrates, reproduces in its individual development, in virtue of certain hereditary processes, a part of its ancestral

[1] As already stated, it will presently appear in England with the title, *The Evolution of Man*.—TRANS.

history. The very word "recapitulation" implies a partial and abbreviated repetition of the course of the original phyletic development, determined by the "laws of heredity and adaptation." Heredity brings about the reproduction of certain evolutionary features; adaptation causes a modification of them by the conditions of the environment—a condensation, disturbance, or falsification. Hence I insisted from the first that the biogenetic law consists of two parts, one positive and palingenetic and the other restrictively-negative and cenogenetic. *Palingenesis* reproduces a part of the original history of the stem; *cenogenesis* disturbs or alters this picture in consequence of subsequent modifications of the original course of development. This distinction is most important, and cannot be too often repeated in view of the persistent misunderstanding of my opponents. It is overlooked by those who (like Plate and Steinmann) grant it only a partial validity, and by those who reject it altogether (like Keibel and Hensen). The embryologist Keibel is the most curious of these, as he has himself afforded a good many proofs of the biogenetic law in his careful descriptive-embryological works. But he has so little mastered it that he has never understood the distinction between palingenesis and cenogenesis.

It is especially unfortunate that one of our most distinguished embryologists, Oscar Hertwig of Berlin, who provided a good deal of evidence in favour of the biogenetic law thirty years ago, has lately joined the opponents of it. His supposed "correction" or modification of it is, as Keibel has rightly said, a complete abandonment of it. Heinrich Schmidt has partly explained the causes of this change in his work on the biogenetic law. They are not unconnected with the psychological metamorphosis which Oscar Hertwig has undergone at Berlin.

In the discourse on "The Development of Biology in the Nineteenth Century," which he delivered at the scientific congress at Aachen in 1900, he openly accepted the dualist principles of vitalism (although he says they are "just as unreliable as the chemico-physical conception of the opposing mechanical school"). The views which he has lately advanced on the worthlessness of Darwinism and the unreliability of phylogenetic hypotheses are diametrically opposed to the opinions he represented at Jena twenty-five years ago, and to those which his brother, Richard Hertwig of Munich, has consistently maintained in his admirable *Manual of Zoology*.

In opposition to the mechanical ontogeny which I formulated in 1866 and embodied in the biogenetic law, a number of other tendencies in embryology afterwards appeared, and, with the common title of "mechanical embryology," branched out in every direction. The chief of these to attract attention thirty years ago were the pseudo-mechanical theories of Wilhelm His, who has rendered great service to ontogeny by his accurate descriptions and faithful illustrations of vertebrate-embryos, but who has no idea of comparative morphology, and so has framed the most extraordinary theories about the nature of organic development. In his *Study of the First Sketch of the Vertebrate-body* (1868), and many later works, His endeavoured to explain the complicated ontogenetic phenomena on direct and simple physical lines by reducing them to elasticity, bending, folding of the embryonic layers, etc., while explicitly rejecting the phylogenetic method; he says that this is "a mere by-way, and quite unnecessary for the explanation of the ontogenetic facts (as direct consequences of physiological principles of development)." As a matter of fact, nature rather plays the part of an ingenious tailor in His's

pseudo-mechanical and tectogenetic speculations, as I have shown in the third chapter of the *Anthropogeny*. Hence they have been humorously called the "tailor theory." However, they misled a few embryologists by opening the way to a direct and purely mechanical explanation of the complex embryonic phenomena. Although they were at first much admired, and immediately afterwards abandoned, they have found a number of supporters lately in various branches of embryology.

The great success that modern experimental physiology achieved by its extensive employment of physical and chemical experiments inspired a hope of attaining similar results in embryology by means of the same "exact" methods. But the application of them in this science is only possible to a slight extent on account of the great complexity of the historical processes and the impossibility of "exactly" determining historical matters. This is true of both branches of evolution, individual and phyletic. Experiments on the origin of species have very little value, as I said before; and this is generally true of embryological experiments also. However, the latter, especially careful experiments on the first stages of ontogenesis, have yielded some interesting results, particularly in regard to the physiology and pathology of the embryo at the earliest stages of development. The *Archiv für Entwickelungs-mechanik*, which is edited by the chief representative of this school, Wilhelm Roux, contains, besides these valuable inquiries, a good number of ontogenetic articles, which partly rely on and partly ignore the biogenetic law.

Psychology and biogeny have been up to the present regarded as the most difficult branches of biology for monistic explanation, and the strongest supports of dualistic vitalism. Both departments become accessible

to monism and a mechanico-causal explanation by means of the biogenetic law. The close correlation which it establishes between individual and phyletic development, and which depends on the interaction of heredity and adaptation, makes it possible to explain both. In regard to the first, I formulated the following principle thirty years ago in my first study of the gastræa theory: "Phylogenesis is the mechanical cause of ontogenesis." This single principle clearly expresses the essence of our monistic conception of organic development:—

> In the future every student will have to declare himself for or against this principle, if in biogeny he is not content with a mere admiration of the wonderful phenomena, but desires to understand their significance. The principle also makes clear the wide gulf that separates the older teleological and dualistic morphology from the modern mechanical and monistic science. If the physiological functions of heredity and adaptation are proved to be the sole causes of organic construction, every kind of teleology, and of dualistic and metaphysical explanation, is excluded from the province of biogeny. The irreconcilable opposition between the leading principles of the two is clear. Either there is or is not a direct and causal connection between ontogeny and phylogeny. Either ontogenesis is a brief compendium of phylogenesis or it is not. Either epigenesis and descent—or pre-formation and creation.

In repeating these principles here, I would lay stress particularly on the fact that, in my opinion, our "mechanical biogeny" is one of the strongest supports of the monistic philosophy.

## Chapter XVII.

# THE VALUE OF LIFE

Changes of life. Aim of life. Progress of life. Historic aims. Historic waves. Value of life in classes and races of men. Psychology of uncivilised races. Savages. Barbarians. Civilised nations. Educated nations. Three stages of development (lower, middle, and higher) in each of the four classes. Individual and social value of civilised life in the five sections of nutrition, reproduction, movement, sensation, and mental life. Estimate of human life.

The value of human life is seen by us to-day, now that evolution is established, in quite a different light from fifty years ago. We are now accustomed to regard man as a natural being, the most highly developed natural being that we know. The same "eternal iron laws" that rule the evolution of the whole cosmos control our own life. Monism teaches that the universe really deserves its name, and is an all-embracing unified whole —whether we call it God or Nature. Monistic anthropology has now established the fact that man is but a tiny part of this vast whole, a placental mammal, developed from a branch of the order of primates in the later Tertiary period. Hence, before we seek to estimate the value of man's life, we will cast a glance at the significance of organic life generally.

An impartial survey of the history of organic life on our planet teaches, first of all, that it is a process of constant change. Millions of animals and plants die every second, while other millions replace them; every individual has his definite period of life, whether it lives only

a few hours, like the one-day fly or the infusorium, or, like the Wellingtonia, the dragon-tree of Orotava, and many other giant trees, lives for thousands of years. Even the species, the collection of like individuals, is just as transitory, and so are the orders and classes that embrace numbers of species of animals and plants. Most species are confined to a single period of the organic history of the earth; few species or genera pass unchanged through several periods, and not a single one has lived in all the periods. Phylogeny, taking its stand on the facts of paleontology, teaches unequivocally that every specific living form has only existed a longer or shorter period in the course of the many (more than a hundred) million years which make up the history of organic life.

Every living being is an end to itself. On this point all unprejudiced thinkers are agreed, whether, like the teleologist, they believe in an entelechy or dominant as regulator of the vital mechanism, or whether they explain the origin of each special living form mechanically by selection and epigenesis. The older anthropistic idea, that animals and plants were created for man's use, and that the relations of organisms to each other were generally regulated by creative design, is no longer accepted in scientific circles. But it is just as true of the species as of the individual that it lives for itself, and looks above all to self-maintenance. Its existence and "end" are transitory. The progressive development of classes and stems leads slowly but surely to the formation of new species. Every special form of life—the individual as well as the species—is therefore merely a biological episode, a passing phenomenal form in the constant change of life. Man is no exception. "Nothing is constant but change," said the old maxim.

The historical succession of species and classes is, both

in the animal and the plant kingdom, accompanied by a slow and steady progress in organisation. This is directly and positively taught by paleontology; its creation-medals, the fossils, are unequivocal and irrefutable witnesses to this phylogenetic advance. I have dealt with the subject in my *History of Creation*, and at the same time shown that both the progressive improvement and the increasing variety of the species can be explained mechanically as necessary consequences of selection. There was no need of a conscious creator or a transcendental purposiveness to effect this. Scientific and thorough proof of this will be found in the three volumes of my *Systematic Phylogeny* (1894). I need only refer briefly to the two conspicuous examples we have in the stem-history of the tissue-plants and that of the vertebrates. Of the metaphyta the ferns are the chief groups in the paleozoic, the gymnosperms in the mesozoic, and the angiosperms in the cenozoic age. Of the vertebrates only fishes are found in the Silurian age, dipneusta only begin in the Devonian, and the first mammals are in the Triassic.

A number of false teleological conclusions have been drawn from these facts of progressive modification of forms, as they are given in paleontology. The latest and most developed form of each stem was taken to be the preconceived aim of the series, and its imperfect predecessors were conceived as preparatory stages to the attainment of this aim. It was like the conduct of many historians, who, when a particular race or State has reached a high rank in civilisation as a result of its natural endowments and favourable conditions of development, hail it as a "chosen people," and regard its imperfect earlier condition as a deliberately conceived preparatory stage. In point of fact, these evolutionary stages were bound

to proceed according as the internal structure (given by heredity) and the outer conditions (provoking adaptation) determined. We cannot admit any conscious direction to a certain end, either in the form of theistic pre-destination or pantheistic finality. For this we must substitute a simple mechanical causality in the sense of psycho-mechanical monism or hylozoism.

Although the stem-history of plants and animals, like the history of humanity, shows a progressive advance taken as a whole, we find a good deal of vacillation in detail. These historical waves are wholly irregular; in periods of decay the hollows of the waves often persist for a long time, and are then succeeded by a fresh rise to the crest of another wave. New and rapidly-advancing groups come to take the place of the old decaying groups, bringing with them a higher stage of organisation. Thus, for instance, the ferns of to-day are only a feeble survival of the huge and varied pteridophyta that formed the most conspicuous part of the paleozoic forests in the Devonian and Carboniferous periods; they were ousted in the Secondary period by their gymnosperm descendants (cycadea and conifers), and these, again, in the Tertiary period by the angiosperm flowering plants. So among the terrestrial reptiles the modern tortoises, serpents, crocodiles, and lizards are only a feeble remnant of the enormous reptile-fauna that dominated the Secondary period, the colossal dinosauri, pterosauri, ichtyosauri, and plesiosauri. They were replaced in the Tertiary period by the smaller but more powerful mammals. In the history of civilisation the Middle Ages form a deep valley between the crests of the waves of classical antiquity and modern culture.

These few examples suffice to show that the various classes and orders of living things have a very different

value when compared with each other. In regard to their intrinsic aim, self-maintenance, it is true that all organisms are on a level, but in their relations to other living things and to nature as a whole they are of very unequal value. Not only may larger animals and plants retain domination for a long time in virtue of their special use or superior force and mass, but small ones may prevail owing to their power of inflicting injury (bacteria, fungi, parasites, etc.). In the same way the value of the various races and nations is very unequal in human history. A small country like Greece has almost dominated the mental life of Europe for more than 2,000 years in virtue of its superior culture. On the other hand, the various tribes of American Indians have, it is true, developed a partial civilisation in some parts (Peru and Central America); but, on the whole, they have proved incapable of advancing.

Though the great differences in the mental life and the civilisation of the higher and lower races are generally known, they are, as a rule, under-valued, and so the value of life at the different levels is falsely estimated. It is civilisation, and the fuller development of the mind that makes civilisation possible, that raise man so much above the other animals, even his nearest animal relatives, the mammals. But this is, as a rule, peculiar to the higher races, and is found only in a very imperfect form or not at all among the lower. These lower races (such as the Veddahs or Australian negroes) are psychologically nearer to the mammals (apes or dogs) than to civilised Europeans; we must, therefore, assign a totally different value to their lives. The views on the subject of European nations which have large colonies in the tropics, and have been in touch with the natives for centuries, are very realistic, and quite different from the

ideas that prevail in Germany. Our idealistic notions, strictly regulated by our academic wisdom and forced by our metaphysicians into the system of their abstract ideal-man, do not at all tally with the facts. Hence we can explain many of the errors of the idealistic philosophy and many of the practical mistakes that have been made in the recently-acquired German colonies; these would have been avoided if we had had a better knowledge of the low psychic life of the natives (*cf.* the writings of Gobineau and Lubbock).

The grave errors that have been maintained in psychology for centuries are mostly due to a neglect of the comparative and genetic methods and the narrow employment of self-observation, or the introspective method; they are also partly due to the fact that metaphysicians generally make their own highly developed mind—a scientifically trained reason—the starting-point of their inquiry, and regard this as representative of the human mind in general, and thus build up their ideal scheme. The gulf between this thoughtful mind of civilised man and the thoughtless animal soul of the savage is enormous—greater than the gulf that separates the latter from the soul of the dog. Kant would have avoided many of the defects of his critical philosophy, and would not have formulated some of his powerful dogmas (such as the immortality of the soul, or the categorical imperative) if he had made a thorough and comparative study of the lower soul of the savage, and phylogenetically deduced the soul of civilised man therefrom.

The extreme importance of this comparison has only been fully appreciated of late years (by Lubbock, Romanes, etc.). Fritz Schultze (of Dresden) made the first valuable attempt in his interesting *Psychology of the*

*Savage* (1900) to give us an "evolutionary psychological description of the savage in respect of intelligence, æsthetics, ethics, and religion." At the same time, he gives us "a history of the natural creation of the human imagination, will, and faith." The first book of this important work deals with thought, the second with will, and the third with the religious ideas of the savage, or "the story of the natural evolution of religion" (fetichism, animism, worship of the heavenly bodies). In an appendix to the second book the author deals with the difficult problems of evolutionary ethics, supporting himself by the authority of the great work of Alexander Sutherland, *The Origin and Growth of the Moral Instinct* (1898). Sutherland divides humanity, in regard to the various stages of civilisation and mental development (not according to racial affinity), into four great classes: 1, Savages; 2, barbarians; 3, civilised races; 4, educated races. As this classification of Sutherland's not only enables us to take a good survey of the various forms of mental development, but is also very useful in connection with the question of the value of life at the different stages, I will briefly reproduce the chief points of his characterisation of the four classes.

I. Savages.—Their food consists of wild natural products (the fruits and roots of plants, and wild animals of all kinds). Most of them are, therefore, fishers or hunters. They are ignorant of agriculture and the breeding of cattle. They live isolated lives in families or scattered in small groups, and have no fixed home. The lowest and oldest savages come very close to the anthropoid apes from which they have descended in bodily structure and habits. We may distinguish three orders in this class—the lower, middle, and higher savages.

*A.* Lower savages, approaching nearest to the ape, pygmies of small stature, four to four and a half feet high (rarely four and three-quarters); the women sometimes only three to three and a half feet. They are woolly-haired and flat-nosed, of a black or dark brown colour, with pointed belly, thin and short legs. They have no homes, and live in forests and caverns, and partly on trees; wander about in small families of ten to forty persons; quite naked, or with just a trace of some primitive garment. Of the lower races now living we must put in this class the Veddahs of Ceylon, the Semangs of the Malay peninsula, the negritos of the Philippines, the Andaman islanders, the Kimos of Madagascar, the Akkas of Guinea, and the Bushmans of South Africa. Other scattered remnants of these ancient negroid dwarfs, which approach closely to the anthropoid apes, still live in various parts of the primitive forests of the Sunda islands (Borneo, Sumatra, Celebes).

The value of the life of these lower savages is like that of the anthropoid apes, or very little higher. All recent travellers who have carefully observed them in their native lands, and studied their bodily structure and psychic life, agree in this opinion. Compare the thorough treatment of the Veddahs of Ceylon in the work of the brothers Sarasin (of which I have given a summary in my *Travels in Ceylon*). Their only interests are food and reproduction, in the same simple form in which we find these among the anthropoid apes (*cf.* chaps. xv. and xxiii. of my *Anthropogeny*). Our own ancestors were probably much the same 10,000 or more years ago. On the strength of fossil remains of pleistocene men Julius Kollmann has shown it to be very probable that similar dwarf-races (with an average

height of four and a half feet) inhabited Europe at that time.

*B.* Middle savages, somewhat larger and less ape-like than the preceding, averaging five to five and a half feet in height. Their homes are rock caverns and shelters from the wind and rain. Though they have shirts and other rudiments of clothing, both sexes generally go naked; they have primitive weapons of wood and stone and rudely-fashioned boats, wander in troops of fifty to two hundred, and have no social organisation; certain races, however, have laws. To this group belong the Australian negroes and Tasmanians, the Ainos of Japan, the Hottentots, Fuegians, Macas, and some of the forest races of Brazil. The value of their life is very little superior to that of the preceding order.

*C.* Higher savages, mostly of average human height (smaller in colder regions), having always simple dwellings (generally of skins or the bark of trees). They have always primitive clothing, and good weapons of stone, bronze, or copper. They wander in troops of one hundred to five hundred, led by prominent but not ruling princes, and exhibiting rudimentary differences of rank. The method of life is determined by hereditary customs. To this group belong many of the primitive inhabitants of India (Todas, Nagas, Curumbas, etc.), the Nicobar islanders, the Samoyeds, and Kamtschadals; in Africa, the negroes of Damara; and most of the Indian tribes of North and South America. Their life is higher than that of the pithecoid lower and middle savages, but less than that of the barbarians.

II. Barbarians or Semi-savages.—The greater part of their food consists of natural products, which they secure with some foresight; hence they have developed agriculture and pasture to a greater or less extent. The

division of labour is slight, each family supplying its own wants. As a rule, a stock of food is provided for the whole year. As a result of this, art begins to develop. They have generally fixed dwellings.

*A*. Lower Barbarians. Dwellings: Simple huts, generally grouped into villages and surrounded with plantations. Clothing worn regularly, but very simple: the men often naked in hot climates or with shirt. Pottery and cooking utensils, tools of stone, wood, or bone. Rudiments of commerce by exchange. Groups of 1,000 to 5,000 persons able to form larger communities; distinctions of rank and warfare. Princes rule according to traditional laws. Of this group we have, in Asia, many of the aboriginal inhabitants of India (Mundas, Khonds, Paharias, Bheels, etc.), the Dyaks of Borneo, the Battaks of Sumatra, Tunguses, Kirgises, etc.; in Africa, the Kaffirs, Bechuanas, and Basutos; in Australasia, the aborigines of New Guinea, New Caledonia, New Hebrides, New Zealand, etc.; and in America, the Iroquois and Thlinkets, and the inhabitants of Nicaragua and Guatemala.

*B*. Middle barbarians. Dwellings good and durable, generally of wood, roofed with cane or straw, forming fine towns. Clothing general, though nudity is not considered immoral. Pottery, weaving, and metal work pretty well developed. Commerce in regular markets, with the use of money. States ruled by kings in accordance with traditional laws, fixed distinctions of rank, communities up to 100,000 persons. To these belong, in Asia, the Calmucks; in Africa, many negro races (Ashantis, Fantis, Fellahs, Shilluks, Mombuttus, Owampos, etc.); in Polynesia, the inhabitants of the Fiji, Tonga, Samoa, and Markesas islands. In Europe the Lapps belonged to this class 200 years ago, the

ancient Germans 2,000 years ago, the Romans before Numa, and the Greeks of the Homeric period.

*C.* Higher barbarians. Dwellings, usually solid stone buildings. Clothing obligatory, weaving habitual occupation of the women, metal work far advanced, tools generally of iron. Restricted commerce, with minted money, no rudder-ships. Crude judicature in fixed courts; rudimentary writing. Masses of people, with progressive division of labour and hereditary distinctions of rank, sometimes reaching half a million souls, under an autonomous ruler. To this class belong, in Asia, most of the Malays (in the large Sunda islands and the peninsula of Malacca), and the nomadic races of Tartars, Arabs, etc.; in Polynesia, the islanders of Tahiti and Hawaii; in Africa, the Somalis and Abyssinians, and the inhabitants of Zanzibar and Madagascar. Of the historic peoples of antiquity we have the Greeks of the time of Solon, the Romans at the beginning of the Republic, the Jews under the Judges, the Anglo-Saxons of the Heptarchy, and the Mexicans and Peruvians at the time of the Spanish invasion.

III. Civilised Races.—Food and complex vital needs are easily satisfied on account of the advanced division of labour and improvement of instruments. Art and science are consequently developed more and more. The increasing specialisation brings about a great elaboration of individual functions, and at the same time a great strengthening of the whole body politic, as there is complete mutual dependence. The citizens see that they must submit to the laws of the State.

*A.* Lower civilised races. Towns with stone walls; vast architectural works in stone; use of the plough in agriculture. War is entrusted to a particular class. Writing firmly established, primitive law-books, fixed

courts. Literature begins to develop. To this group belong in Asia the inhabitants of Thibet, Bhutan, Nepaul, Laos, Annam, Korea, Manchuria, and the settled Arabs and Turcomans; in Africa the Algerians, Tunisians, Moors, Kabyles, Tuaregs, etc. Of historical races we have the ancient Egyptians, Phenicians, Assyrians, Babylonians, Carthaginians, the Greeks after Marathon, the Romans of the time of Hannibal, and the English under the Norman kings.

*B.* Middle civilised races. Beautiful temples and palaces, built of stone and brick. Windows come into use, and sailing-ships. Commerce expands. Writing and written books are general; the literary instruction of the young is attended to. Militarism is further developed; so are legislation and advocacy. Of these we have in Asia the Persians, Afghans, Birmans, and Siamese; in Europe the Finns and Magyars of the eighteenth century. Of historical peoples we must count among them the Greeks of the age of Pericles, the Romans of the later Republic, the Jews under the Macedonian rule, France under the first Capets, and England under the Plantagenets.

*C.* Higher civilised races. Stone houses general; streets paved; chimneys, canals, water and wind-mills. Beginnings of scientific navigation and warfare. Writing general, written books widely distributed, literature esteemed. The highly centralised State embraces communities of ten millions or more. Fixed and written codes of law are officially promulgated and applied by courts to particular cases. Numbers of Government officials have settled rank. To this group belong in Asia the Chinese, Japanese, and Hindoos; also the Turks and the various Republics of South America, etc. In history we have the Romans of the Empire, and the

Italians, French, English, and Germans of the fifteenth century.

IV. Cultivated Races.—Food and other needs are artificially supplied with the greatest ease and in abundance, human labour being replaced by natural forces. The social organisation grows, and facilitates the play of all the social forces, and man obtains a great freedom to cultivate his mental and æsthetic qualities. Printing is in general use, the education of the young one of the first duties. War becomes less important; rank and fame depend less on military bravery than on mental superiority. Legislation is influenced by representatives of the people. Art and science are increasingly promoted by State-aid.

Alexander Sutherland distinguishes three stages of development—the lower, middle, and higher—in the fourth as well as in the preceding classes. To the first stage he assigns "the leading nations of Europe and their offshoots, such as the United States of North America." For the second stage—middle cultured races—he gives a programme that may be carried out in three or four hundred years' time, with this definition: "All men are well fed and housed; war is universally condemned, but breaks out now and again. Small armies and fleets of all the nations co-operate as a sort of international police; commercial and industrial life are directed according to the moral precepts of sympathy; culture is general; crime and punishment rare." Of the third and highest stage Sutherland merely says: "Too bold a subject for prophecy, that may not come for 1000–2000 years yet." This division seems to me too vague and unsatisfactory, in the sense that it does not properly emphasise the civilisation of the nineteenth century in contrast with all preceding stages. It would be better to distinguish

*provisionally* the following stages in modern civilisation: first, sixteenth to eighteenth century; second, nineteenth century; and third, twentieth century and the future.

*A*. Lower cultured races (Europe, sixteenth to eighteenth century). At the commencement of this period, the first half of the sixteenth century, we notice the preparatory movements to the full growth of mental life which was to achieve such great results in the following periods: 1. The cosmic system of Copernicus (1543) maintained by Galileo (1592). 2. The discovery of America by Columbus (1492) and of the East Indies by Vasco de Gama (1498), the first circumnavigation of the earth by Magellan (1520), and the evidence it afforded of the rotundity of the earth. 3. The liberation of the mind of Europe from the papal yoke by Martin Luther (1517), and the repulse of the prevailing superstition by the spread of the Reformation. 4. The new impulse to scientific investigation independently of scholasticism and the Church and of the philosophy of Aristotle; the founding of empirical science by Francis Bacon (1620). 5. The spread of scientific knowledge by the press (Gutenberg, 1450) and wood-engraving. The way was prepared for modern civilisation by these and other advances in the sixteenth century, and it quickly arose above the barbaric level of the Middle Ages. However, it was confined at first within narrow limits, as the reactionary civilisation of the Middle Ages was still powerful in political and social life, and the struggle against superstition and unreason made slow progress. The French Revolution (1792) at last gave a great impetus in practical directions.

*B*. Middle cultured races. This name may be given to the leading nations of Europe and North America in the nineteenth century. We may illustrate in the

following achievements the great advance which this "century of science" made as compared with all preceding ages: 1. Deepening, experimental grounding, and general spread of a knowledge of nature, independent establishment of many new branches of science, founding of the cell-theory (1838), the law of energy (1845), and the theory of evolution (1859). 2. Practical and comprehensive application of this theoretical science to all branches of art and industry; especially 3. the overcoming of time and space by the extraordinary speed of transit (steam-boats, railways, telegraphs, electrotechnics). 4. Construction of the monistic and realistic philosophy, in opposition to the prevailing dualistic and mystical views. 5. Increasing influence of rational scientific instruction and abandonment of the religious fiction of the Churches. 6. Increasing self-consciousness of the nations on account of having a share in Government and legislation; extinction of the belief in the divine right of rulers. New distinction of classes. However, these great advances, to which we children of the nineteenth century may point with pride, are far from being universal; they are struggling daily with reactionary views and powers in Church and State, with militarism, and with ancient and venerable immorality of every kind.

*C.* The higher culture which we are just beginning to glimpse will set itself the task of creating as happy and contented a life as possible for all men. A perfect ethic, free from all religious dogma and based on a clear knowledge of natural law, will be found in the golden rule, "Love thy neighbour as thyself." Reason tells us that a perfect State must provide the greatest possible happiness for every individual that belongs to it. The adjustment of a rational balance between egoism and altruism is the aim of our monistic ethic. Many barbaric customs

that are still regarded as necessary—war, duelling, ecclesiastical power, etc.—will be abolished. Legal decisions will suffice to settle the quarrels of nations, as they now do of individuals. The chief interest of the State will be, not the formation of as strong a military force as possible, but the best possible instruction of its young, with special attention to art and science. The improvement of technical methods, owing to new discoveries in physics and chemistry, will bring greater satisfaction of our needs of life. The artificial production of albumin will provide plenty of food for all. A rational reform of the marriage-relations will increase the happiness of family life.

The darker sides of modern life, of which we are all more or less sensitive, have been laid bare by Max Nordau in his *Conventional Lies of Civilisation*. They will be greatly altered if reason is permitted to have its way in practical life, and the present evil customs, based on antiquated dogmas, are suppressed. But, in spite of all these shades, the luminous features of modern civilisation are so great that we look to the future with hope and confidence. We need only glance back half a century, and compare life to-day with what it was then, in order to realise the progress made. If we regard the modern State as an elaborate organism (a " social individual of the first order "), and compare its citizens to the cells of a higher tissue-animal, the difference between the State of to-day and the crudest family-groups of savages is not less than that between a higher metazoon (such as a vertebrate) and a cœnobium of protozoa. The progressive division of labour, on the one hand, and the centralisation of society, on the other, prepare the social body for higher functions than in isolation, and proportionately increase the worth of its life. To see this

more clearly, let us compare the personal and the social value of life in the five chief fields of vital activity—nutrition, reproduction, movement, sensation, and mental life.

The first need of the individual organism, self-maintenance, is met in a much more perfect manner in the modern State than it was formerly. The savage is satisfied with the raw products of nature, with hunting, fishing, and the gathering of roots and fruits. Agriculture and pasturage come later. Many stages of barbarism and lower civilisation must be passed before the conditions of feeding, housing, and clothing provide a secure and comfortable existence for man, and permit the addition of æsthetic and intellectual interests to the indispensable search for food.

The feeding and condition of the social body as a whole have been improved by modern civilisation, just as in the case of the individual. The progress of chemistry and agriculture has enabled us to produce food in larger quantities. The ease and rapidity of transfer allow it to be distributed over the whole earth. Scientific medicine and hygiene have discovered many means of diminishing the dangers of disease and preventing its occurrence. By means of public baths, gymnasiums, popular restaurants, public gardens, etc., greater care is taken of the health of the community. The arrangement of modern houses, and their heating and lighting, have been immensely improved. Modern social politics strives more and more to extend these benefits of civilisation to the lower classes. Philanthropic societies are busy supplying the material and spiritual wants of various classes of sufferers. It is true there is still a broad margin for the improvement of the national well-being. But, on the whole, it cannot be denied that the provision

of food in the modern State is an immense advance upon that of the Middle Ages and of the barbaric period.

The great value of modern civilisation and its vast progress beyond the condition of the savage is seen in no branch of physiology so conspicuously as in the wonderful process of reproduction and the maintenance of the species. In most savages and barbarians the satisfaction of their powerful sexual impulse is at the same low stage as in the ape and other mammals. The woman is merely an object of lust to the man, or even a slave without rights, bought and exchanged like all other property. Improvement is slow and gradual in the value of this property, until it reaches a high guarantee of permanency in the formal marriage. The family life proves a source of higher and finer enjoyment for both parties. The position of woman advances with civilisation; her rights obtain further recognition, and in addition to sensual love the psychic relation of man and wife begins to develop. The common concern for the proper care and education of the children, which we find to an extent even in the case of many animals, leads to the further development of family life and the founding of the school. With the advent of a higher stage of civilisation begins the refinement of sexual love, which finds its highest satisfaction, not in the momentary gratification of the sex-impulse, but in the spiritual relation of the sexes and their constant and intimate intercourse. The beautiful then unites with the good and the true to form a harmonious trinity. Hence love has been for thousands of years the chief source of the æsthetic uplifting of man in every respect; the arts —poetry, music, painting, and sculpture—have drawn inexhaustively from this source. However, for the individual civilised human being this higher love is of value,

not only because it satisfies the natural and irresistible sex-impulse in its noblest form, but also because the mutual influence of the sexes, their complementary qualities and their common enjoyment of the highest ideal good, has a great effect upon individual character. A good and happy marriage—which is not very common to-day—ought to be regarded, both psychologically and physiologically, as one of the most important ends of life by every individual of the higher nations.

As a pure marriage is the best form of family life and the most solid foundation of the State, its high social value is at once evident. The attraction and mutual devotion of the sexes fulfils in the highest degree the ethical golden rule—the balance of egoism and altruism. As Fritz Schultze very truly says in his *Comparative Psychology*:—

> We must not seek the causes of this altruism in the transcendental region of the supernatural, or in any metaphysical abstraction, but must go back to the very real and natural qualities of the organic being—and then there can be no question that the organic sex-impulse, at once physical and psychical, is the first and enduring source of all love, however spiritual, and of all real ethical and sympathetic feelings and the morality founded thereon. There are two primitive instincts in all organisms: that of self-maintenance and that of the maintenance of the species. The one is the strong impulse of egoism, the other the spring of altruism: from the one come all unfriendly, and from the other all friendly, feelings. Every being seeks first to nourish and protect itself in virtue of its instinct of self-maintenance. But soon the magic of the instinct for the maintenance of the species works in it; it feels the sex impulse, and thinks it is only satisfying its egoistic lust in yielding to it. In this it is wrong; it is not really serving itself, but the whole, the species, the genus. The ardour of love burns in it; and however sensual this love is at first, the new feeling is undeniably a feeling of belonging to another and of mutual consideration, looking not only to itself, but to another; not only to its own good, but to that of another, and finding its own good only in that of the other. And though this feeling at first only unites the two parents, it enlarges when children enter into life, and is extended to them in the form of parental love. Thus, out of the

sex-impulse of the maintenance of the species, with its strong physical and psychic roots, is developed the love of spouses, of parents, of children, and of neighbour. Disinterested egoism goes even to the extent of sacrificing its own life for its young; in this organic and natural family-love, and in the sense of the family that comes of it, we find the roots of all sympathetic and really ethical altruistic feelings; from this it widens out to larger spheres. Hence, the family is rightly held to be the chief source of all real moral feeling and life, not only in the human, but also in the animal world.

The further ennoblement of family-life in the advance of civilisation will give fresh proofs of the truth of this appreciation.

We now turn to consider the advantages that modern civilisation offers in the way of movement in contrast to the simple methods of locomotion of the savage. We may point out first that the earliest men, like their ancestors, the anthropoid apes, lived in trees, and only gradually began to run on the ground. Some of the higher savages began to use the horse for riding, and to tame it. Many inhabitants of the coast or islands began at an early period to make boats. Later the barbaric tribes invented the wagon, and much later again streets were paved and vehicles improved by civilised races. But the nineteenth century brought the invaluable means of rapid and convenient travelling by means of steam-boats and railways. The whole problem of transit was revolutionised, and in the last few decades further vast changes have been made owing to the advance of electricity. Modern ideas of time and space are quite different from those of our parents sixty years ago, or our grand-parents ninety years ago. In our expresses we cover in an hour a stretch of country that the mail-coach took five times and the foot passenger ten times as long to cover. As the experiments with the Berlin electric railway have lately shown, we can now travel 200

kilometers in an hour. The journey from Europe to India now takes three weeks, whereas the earlier sailing vessel took as many months. The immense saving of time that we make is equivalent to a lengthening of our own life. This applies also to the more rapid transit provided by balloons, automobiles, bicycles, etc. It is easy to estimate the value of these improvements; but it is only fully appreciated by those who have lived long in an uncivilised country without roads, or among savages whose legs are their only means of locomotion.

This progress in the means of transit is not less valuable socially than personally. If we conceive the State as a unified organism of the higher order, the development of its means of transit corresponds in many ways to that of the circulation of the blood in the vertebrate frame. The easy, rapid, and convenient transport of the means of life from the centre to the most distant parts of the land, and the corresponding development of the network of railways and steamboat routes, are to a certain extent direct tests of the degree of civilisation. To this we must add the creation of a large number of offices which provide steady employment and means of subsistence for many thousands.

To compare the complex sensations of civilised man with the much simpler ones of the savage we must consider first the functions of the outer organs of sense, and then the internal sense-processes in the cortex of the brain. Fritz Schultze has pointed out in his *Psychology of the Savage*, in regard to both sets of organs, that the savage is a man of sense-life, the civilised human being a man of mind-life. When we remember that our higher psychic functions (sensation, will, presentation, and thought) are anatomically connected with the phronema (the thought-organ in the cortex),

and the inner sense-perception with the central sensorium (in the sense-centres of the cortex), we shall expect to find the latter more developed in the savage and the former in civilised man. The external sense-action is more intense in quantity, but weaker in quality, in the savage than in civilised man; this is especially true of the finer and more complex sense-functions which we call æsthetic sensations, and regard as the source of art and poetry. Most strongly developed of all in the savage is the power of perceiving distant objects (sight, hearing, smell), as they warn him of the dangers about him. It is just the reverse with the subjective and proximate feelings that are excited by the immediate touch of objects, and are the special instruments of sensual enjoyment—taste, sex-sense, touch, and feeling of temperature. But in both kinds of sense-action the civilised man is far ahead of the savage in respect of the finer shades of feeling and æsthetic education. Moreover, modern civilisation has provided man with various means of vastly increasing and improving the natural power of his senses. We need only mention the fields of knowledge that have been opened to us by the microscope and telescope, the refined chemical methods of modern cooking, etc. The finer æsthetic enjoyment which our advanced art affords —plastic art for the eye, music for the ear, perfumery for the nose, cuisine for the tongue—is generally unintelligible to the savage, although he can see much further, and hear and smell much more acutely, than civilised man. And in the senses of near objects (taste, touch, temperature) the senses of the savages are more coarse, and incapable of the fine gradations of civilised man.

This more refined sense-life and the accompanying æsthetic enjoyment have no less social than personal

value. We have, in the first place, the incalculable treasure of modern art and science, their promotion by the State, and their embodiment in the training of the young. In the future the higher races are likely to give more attention to this, training the senses of children as well as their intelligence from the earliest years, leading them to a closer observation of nature and reproduction of its forms by drawing and painting. The art-sense must also be fostered by the exhibition of models and by æsthetic exercises, a larger place must be given to artistic education along with the acquisition of real knowledge, and an appreciation of the beauties of nature must be created by means of walks and travels. Then the children of civilised races will have the inexhaustible sources of the finest and noblest pleasures in life opened to them in good time.

The higher psychic activity that civilised man calls his "mental life," and that is so often regarded as a kind of miracle, is merely a higher development of the psychic function we find at a lower level in the savage, and is shared by him with the higher vertebrates. Comparative psychology shows us, as I have explained in the seventh chapter of the *Riddle*, the long scale of development, which leads from the simple cell-soul of the protist up to the intelligence of man. I have already dealt in various chapters with this point, and need not enlarge on it any further to estimate the high personal value of mental life in every civilised human being. It is enough to remind the reader of the vast treasures of knowledge that lie open to every one of us at the commencement of the twentieth century—treasures of which our grandparents at the beginning of last century had not the slightest presentiment.

Just as the individual has experienced a great advance

in the value of his personal life by the higher culture of the nineteenth century, so the modern State itself has benefited by it in many ways. The many discoveries made in every branch of science and technical industry, the great advance in commerce and industrial life, in art and science, were bound to bring about a higher development of the whole mind of a modern community. Never, in the whole of history, has true science risen to such an astounding height as it has at the beginning of the twentieth century. Never before did the human mind penetrate so deeply into the darkest mysteries of nature, never did it rise so high to a sense of the unity of nature and make such practical use of its knowledge. These brilliant triumphs of modern civilisation have, however, only been made possible by the various forces co-operating in a vast division of labour, and by the great nations utilising their resources zealously for the attainment of the common end.

But we are still far from the attainment of the ideal. The social organisation of our States is advanced only on one side; it is very reactionary on other sides. Unfortunately, the words of Wallace which I quoted in the *Riddle* remain as true as ever. Our modern States will only pass beyond this condition in the course of the twentieth century if they adopt pure reason as their guide instead of faith and traditional authority, and if they come at length to understand aright "man's place in nature."

If we take a summary view of all that I have said on the increase in the value of human life by the progress of civilisation, there can be no doubt that both the personal and the social value of life are now far higher than they were in the days of our savage ancestors. Modern life is infinitely rich in the high spiritual interests that

attach to the possession of advanced art and science. We live in peace and comfort in orderly social and civic communities, which have every care of person and property. Our personal life is a hundred times finer, longer, and more valuable than that of the savage, because it is a hundred times richer in interests, experiences, and pleasures. It is true that within the limits of civilisation the differences in the value of life are enormous. The greater the differentiation of conditions and classes in consequence of division of labour, the greater become the differences between the educated and uneducated sections of the community, and between their interests and needs, and, therefore, the value of their lives. This difference is naturally most conspicuous if we consider the leading minds and the greatest heights of the culture of the century, and compare these with the average man and the masses, which wander far below in the valley, treading their monotonous and weary way in a more or less stupid condition.

The State thinks quite otherwise than the individual man does of the personal worth of his life and that of his fellows. The modern State often demands for its protection the military service of all its citizens. In the eyes of our ministers of justice the value of life is the same whether there be question of an embryo of seven months or a new-born child (still without consciousness), an idiot or a genius. This difference between the personal and the social estimate of life runs through the whole of our moral principles. War is still believed by highly civilised nations to be an unavoidable evil, just as barbarians think of individual murder or blood-revenge; yet the murder of masses for which the modern State uses its greatest resources is in flagrant contradiction to the gentle doctrine of Christian charity which it

employs its priests to preach every Sunday with all solemnity.

The chief task of the modern State is to bring about a natural harmony between the social and the personal estimate of human life. For this purpose we need, above all, a thorough reform of education, the administration of justice, and the social organisation. Only then can we get rid of that medieval barbarism of which Wallace speaks; to-day it finds expression triumphantly in our penal laws, our caste-privileges, the scholastic nature of our education, and the despotism of the Church.

For each individual organism the life of the individual is the first aim and the standard of value. On this rests the universal struggle for self-maintenance, which can be reduced in the inorganic world to the physical law of inertia. To this subjective estimate of life is opposed the objective, which proceeds on the value of the individual to the outer world. This objective value increases as the organism developes and presses into the general stream of life. The chief of these relations are those that come of the division of labour among individuals and their association in higher groups. This is equally true of the cell-states which we call tissues and persons, of the higher stocks of plants and animals, and of the herds and communities of the higher animals and men. The more these develop by progressive division of labour and the greater the mutual need of the differentiated individuals, so much the higher rises the objective value of the life of the latter for the whole, and so much the lower sinks the subjective value of the individual. Hence arises a constant struggle between the interests of individuals who follow their special life-aim and those of the State, for which they have no value except as parts of the whole.

## Chapter XVIII.

## MORALITY

Dualistic ethics. The categorical imperative. Monistic ethics. Morals and adaptation. Variation and adaptation. Habit. Chemistry of habit. Trophic stimuli. Habit in inorganic bodies. Instincts. Social instincts. Instinct and morality. Right and duty. Morals and morality. The good and the bad. Morals and fashions. Sexual selection. Fashion and the feeling of shame. Fashion and reason. Ceremonies and cults. Mysteries and sacraments. Baptism. The Lord's Supper. Transubstantiation. The miracle of redemption. Papal sacraments. Marriage. Modern fashions. Honour. Phylogeny of morals.

The practical life of man is, like that of all the social higher animals, ruled by impulses and customs which we describe as "moral." The science of morality, ethics, is regarded by the dualists as a mental science, and closely connected with religion on the one hand and psychology on the other. During the nineteenth century this dualistic view retained its popularity especially because the great authority of Kant, with his dogma of the categorical imperative, seemed to have given it a solid foundation, and because it agreed admirably with the teaching of the Church. Monism, on the other hand, regards ethics as a natural science, and starts from the principle that morality is not supernatural in origin, but has been built up by adaptation of the social mammals to the conditions of existence, and thus may be traced eventually to physical laws. Hence modern biology sees no metaphysical miracle in morality, but the action of physiological functions.

Our whole modern civilisation clings to the erroneous ideas which traditional morality, founded on revelation, and closely connected with ecclesiastical teaching, has imposed upon it. Christianity has taken over the ten commandments from Judaism, and blended them with a mystical Platonism into a towering structure of ethics. Kant especially lent support to it in recent years with his *Critique of Practical Reason*, and his three central dogmas. The close connection of these three dogmas with each other, and their positive influence on ethics, were particularly important through Kant formulating the further dogma of the categorical imperative.

The great authority which Kant's dualist philosophy obtained is largely owing to the fact that he subordinated pure reason to practical reason. The vague moral law for which Kant claimed absolute universality is expressed in his categorical imperative as follows: "So act that the maxim (or the subjective principle of your will) may at the same time serve as a general law." I have shown in the nineteenth chapter of the *Riddle* that this categorical imperative is, like the thing-in-itself, an outcome of dogmatic, not critical, principles. As Schopenhauer says:—

Kant's categorical imperative is generally quoted in our day under the more modest and convenient title of "the moral law." The daily writers of compendiums think they have founded the science of ethics when they appeal to this apparently innate "moral law," and then build on it that wordy and confused tissue of phrases with which they manage to make the simplest and clearest features of life unintelligible, without having ever seriously asked themselves whether there really is any such convenient code of morality written in our head, breast, or heart. This broad cushion is snatched from under morality when we prove that Kant's categorical imperative of the practical reason is *a wholly unjustified, baseless, and imaginative assumption.*

Kant's categorical imperative is a mere dogma, and, like his whole theory of practical reason, rests on dogmatic

and not critical grounds. It is a fiction of faith, and directly opposed to the empirical principles of pure reason.

The notion of duty, which the categorical imperative represents as a vague *à priori* law implanted in the human mind—a kind of moral instinct—can, as a matter of fact, be traced to a long series of phyletic modifications of the phronema of the cortex. Duty is a social sense that has been evolved *à posteriori* as a result of the complicated relations of the egoism of individuals and the altruism of the community. The sense of duty, or conscience, is the amenability of the will to the feeling of obligation, which varies very considerably in individuals.

A scientific study of the moral law, on the basis of physiology, evolution, ethnography, and history, teaches us that its precepts rest on biological grounds, and have been developed in a natural way. The whole of our modern morality and social and juridical order have evolved in the course of the nineteenth century out of the earlier and lower conditions which we now generally regard as things of the past. The social morality of the eighteenth century proceeded, in its turn, from that of the seventeenth and sixteenth centuries, and still further from that of the Middle Ages, with its despotism, fanaticism, Inquisition, and witch-trials. It is equally clear from modern ethnography and the comparative psychology of races that the morality of barbarous races has been evolved gradually from the lower social rules of savage tribes, and that these differ only in degree, not in kind, from the instincts of the apes and other social vertebrates. The comparative psychology of the vertebrates shows, further, that the social instincts of the mammals and birds have arisen from the lower stages of

the reptiles and amphibia, and these in turn from those of the fishes and the lowest vertebrates. Finally, the phylogeny of the vertebrates proves that this highly-developed stem has advanced through a long series of invertebrate ancestors (chordonia, vermalia, gastræada) from the protists by a process of gradual modification. We find, even among these unicellulars (first protophyta, then protozoa), the important principle which lies at the base of morality, association, or the formation of communities. The adaptation of the united cell-individuals to each other and to the common environment is the physiological foundation of the first traces of morality among the protists. All the unicellulars that abandon their isolated eremitic lives, and unite to form communities, are compelled to restrict their natural egoism, and make concessions to altruism in the common interest. Even in the globular cœnobia of volvox and magosphæra the special form and movement and mode of reproduction are determined by the compromise between the egoistic instincts of the individual cells and the altruistic need of the community.

Morality, whether we take it in the narrower or broader sense, can always be traced to the physiological function of adaptation, which is closely connected through nutrition with the self-maintenance of the organism. The change in the plasm which adaptation brings about is always based on the chemical energy of metabolism (chap. ix.). Hence it will be as well to have a clear idea of the nature of adaptation. I defined it as follows in my *General Morphology* :—

Adaptation or variation is a general physiological function of organisms, closely connected with their radical function of nutrition. It expresses itself in the fact that every organism may be modified by the influence of the environment, and may acquire characters which were wanting in

its ancestors. The causes of this variability are chiefly found in a material correlation between parts of the organism and the outer world. Variability or adaptability is not, therefore, a special organic function, but depends on the material, physico-chemical process of nutrition.

I have developed this conception of adaptation in the tenth chapter of the *History of Creation*.

The nature of the adaptation and its relation to variation are often conceived in different ways from that I have defined. Quite recently Ludwig Plate has restricted the idea, and understood by adaptation only variations that are *useful* to the organism. He severely criticises my broader definition, and calls it "a palpable error," suggesting that I only retain it because I am not open to conviction. If I wanted to return this grave charge, I might point to Plate's one-sided and perverse treatment of my biogenetic law. Instead of doing this I will only observe that I think the restriction of adaptation to useful variations is untenable and misleading. There are in the life of man and of other organisms thousands of habits and instincts that are not useful, but either indifferent or injurious to the organism, yet certainly come under the head of adaptation, are maintained by heredity, and modify the form. We find adaptations of all sorts—partly useful, partly indifferent, partly injurious (the result of education, training, distortion, etc.)—in the life of man, and the domestic animals and plants. I need only refer to the influence of fashion and the school. Even the origin of the useless (and often injurious) rudimentary organs depends on adaptation.

Habit is a second nature, says an old proverb. This is a profound truth, the full appreciation of which came to us through Lamarck's theory of descent. The formation of a habit consists in the frequent repetition of one physiological act, and so is in principle reducible to

cumulative or functional adaptation. Through this frequent repetition of one and the same act, which is closely connected with the memory of the plasm, a permanent modification is caused, either in a positive or a negative sense; *positively* the organ is developed and strengthened by exercise, *negatively* it is atrophied or enfeebled by disuse. When this accumulation of slight changes continues, the effect of adaptation goes so far in time as to produce new organs by progressive modification, or to cause actual organs to become useless and rudimentary, and finally disappear, owing to regressive metamorphosis.

When we make a careful study of the simpler processes of habit in the lower organisms, we see that they depend, like all other adaptations, on chemical changes in the plasm, and that these are provoked by trophic stimuli—that is to say, by external action on the metabolism. As Ostwald rightly says: "The most important function of organisms is the conversion of the various chemical energies into each other. The chemical energy that is taken into the organism as food is not generally capable of being applied directly to its purposes, but needs some further preparation. Every cell is a chemical laboratory, in which the most varied reactions take place without fires and retorts. The most frequently employed means in this is probably the catalytic acceleration of the usable and the catalytic retardation of the useless reactions. As a proof of this we have the regular presence of these enzyma in all organisms." In this the greatest importance attaches to memory, which I regard with Hering as a general property of living substance, "in virtue of which certain processes in the living being leave effects behind them that facilitate the repetition of

the processes." I agree with Ostwald that "the importance of this property cannot be exaggerated. In its more general forms it effects adaptation and heredity, in its highest development the conscious memory." While the latter, and consciousness in general, reach the highest stage in the mental life of civilised man, the adaptation of the monera remains at the lowest stage. Among the latter the bacteria especially, which have assumed the most varied and important relations to other organisms in spite of the simplicity of their structure, show that this manifold adaptation depends on the formation of habits in the plasm, and is solely based on their chemical energy, or their invisible molecular structure. Once more the monera form a connecting link between the organic and inorganic; they fill up the deep gulf, from the point of view of energy, that seems to yawn between "animated" organisms and "lifeless" bodies.

According to the prevailing view, habit is a purely biological process, but there are processes even in inorganic nature which come under this head in the broader sense. Ostwald gives the following illustration :—

> If we take two equal tubes of thin nitric acid and dissolve a little metallic copper in one of them, the liquid will acquire the power to dissolve a second piece of the same metal more quickly than the one that remains unchanged. The cause of this phenomenon—which may be observed in the same way with mercury or silver and nitric acid—is that the lower oxydes of nitrogen that are formed in dissolving the metal accelerate the action of the nitric acid catalytically on the fresh metal. The same effect is produced if you put part of these oxydes in the acid; it then acts much more rapidly than pure acid. The formation of a habit consists, therefore, in the production of a catalytic acceleration during the reaction.

We may not only compare inorganic habit with organic adaptation, which we call habit or practice, but also with "imitation," which implies a catalytic transfer of habits to socially united living beings.

By instincts were formerly understood, as a rule, the unconscious impulses of animals which led to purposive actions, and it was believed that every species of animal had special instincts implanted in it by the creator. Animals were thought, according to Descartes' view, to be unconscious machines whose actions proceed with unvarying constancy in the particular form that God had ordained. Although this antiquated theory of instinct is still taught by many dualistic metaphysicians and theologians, it has long since been demolished by the monistic theory of evolution. Lamarck had observed that most instincts are formed by habit and adaptation, and then transmitted by heredity. Darwin and Romanes especially showed afterwards that these inherited habits are subject to the same laws of variation as other physiological functions. However, Weismann has recently taken great pains in his *Lectures on the Theory of Descent* (xxiii.) to refute this idea, and in general the hypothesis of an inheritance of acquired characters, because it will not harmonise with his theory of the germ-plasm. Ernst Heinrich Ziegler, who has recently (1904) published a subtle analysis of former and present ideas of instinct, agrees with Weismann that "all instincts are due to selection, and that they have their roots not in the practice of the individual life, but in the variations of the germ." But where else can we find the cause of these "germ-variations" except in the laws of direct and indirect adaptation? In my opinion, it is just the reverse; the remarkable phenomena of instinct yield a mass of evidence of progressive heredity, completely in the sense of Lamarck and Darwin.

The great majority of organisms live social lives, and so are united by the link of common interests. Of all the relations which determine the existence of the

species, the chief are those which bind the individual to other individuals of the species. This is at once clear from the laws of sexual propagation. Moreover, the association of individuals is a great advantage in the struggle for existence. In the case of the higher animals this association becomes particularly important, because it is accompanied by an extensive division of labour. Then arises the antithesis of the personal egoism and the communal altruism; and in human societies the opposition of the two instincts is all the greater when reason recognises that each has a right to satisfaction. Social habits become moral habits, and their laws are afterwards taught as sacred duties, and form the basis of the juridical order.

The morals of nations, so rich in psychological and sociological interest, are nothing more than social instincts, acquired by adaptation, and passed on from generation to generation by heredity. An attempt has been made to distinguish between the two kinds of habit by describing the instincts of animals as constant vital functions based on their physical organisation, and the habits or morals of human beings as mental powers maintained by a spiritual tradition. This distinction has, however, been excluded by the modern physiological teaching that men's morals are, like all their other psychic functions, based physiologically on the organisation of their brain. The habits of the individual man, which have been formed by adaptation to his personal conditions, become hereditary in his family; and these family usages can no more be sharply distinguished from the general morals of the community than these can be from the precepts of the Church and the laws of the State.

When a certain habit is regarded by all the members

of a community as important, its cultivation favoured and its breach punished, it is raised to the position of a duty. This is true even in the case of the herds of mammals (apes, gregarious carnivora, and ungulates) and the flocks of social birds (hens, geese, ducks). The laws which have been formed in these cases by the higher development of social instincts are particularly striking and equivalent to those of savage tribes when conspicuous individuals (old or strong males) have acquired a leadership of the troop, and successfully ensure the observance of the proper habits or duties. Many of these organised bands are in some respects higher than the savages at the lowest stages who live in isolated families, or only form loose temporary associations of a few families. The great progress made by comparative psychology and ethnology, and historical and pre-historical research, in the second half of the nineteenth century, confirms us in the conviction that a long scale of intermediate stages joins the rudiments of law in the social primates and other mammals to the sense of law in the lower savage, and this again to that of the barbarian and the civilised human being—right up to the science of law in modern Europe.

Like civil laws, the commands of religion come originally from the morals of the savage, and eventually from the social instincts of the primates. The important province of mental life to which we give the vague name of religion was developed at an early stage among the pre-historic races from whom we all descend. When we study its origin from the point of view of empirical psychology and monistic evolution, we find that religion has arisen polyphyletically from different sources—ancestor-worship, the desire of personal immortality, the craving for a causal explanation of phenomena, superstition of various kinds, the strengthening of the moral law

by the authority of a divine law-giver, etc. According as the imagination of the savage or the barbarian followed one or other of these lines it raised up hundreds of religious forms. Only a few of them survived in the struggle for existence, and acquired (at least outwardly) dominion over the modern mind. But as independent and impartial science advances in our time, religion is purified of superstition and turns more and more to morality.

The obedience to the "divine commands" which religion demands of its followers is often transferred by human society to rules that have arisen from social customs of subordinate kinds. Thus we get the familiar confusion of manners and morals, of conventional outer deportment and real inner morality. The ideas of good and bad, morality and immorality, are subjected to arbitrary definitions. In this a great part is played by the moral pressure which is exercised by conventional ideas in the social body on the conduct and minds of its members. However clearly and rationally the individual thinks about the important questions of practical life, he has to yield to the tyranny of traditional and often quite irrational customs. As a matter of fact, both in life and in the nature of the case practical reason does take that precedence of pure reason which Kant claimed.

The tyranny of custom in practical life does not depend merely on the authority of social usage, but also on the power of selection. Just as natural selection ensures the relative constancy of the specific form in the origin of the animal and plant species, so it has a powerful effect on the origin of morals and customs. An important factor in this is mimetic adaptation, or mimicry, the apeing or imitating of certain forms or fashions by various classes of animals. This is unconscious in the case of many orders of insects, butterflies,

beetles, hymenoptera, etc. When insects of a certain family come to resemble in their outer form and colour and design those of another family, they obtain the protection or other advantages which these particular characters give in the struggle for life. Darwin, Wallace, Weismann, Fritz Müller, Bates, and others, have shown in numbers of instances how the origin of these deceptive resemblances can be traced to natural selection, and how important they are in the formation of the species. But many customs and usages in human life arise in just the same way, partly by conscious and partly by unconscious imitation. Of these the varying external forms which we call "fashions" have a most important influence in practical life. The phrase "fashion-ape," when used in a scientific sense, is not merely an expression of contempt, but has also a profound meaning; it correctly indicates the origin of fashions by imitation, and also the peculiar resemblance we find in this respect between man and his cousins, the apes. Sexual selection among the primates has a good deal to do with this.

The great importance which Darwin ascribes in his *Descent of Man* to the æsthetic selection of the respective sexes is equally true of man and of all the higher vertebrates that have a feeling of beauty, especially the amniotes (mammals, birds, and reptiles). The beautiful colouring and marking and ornamentation which distinguish the males from the females are due entirely to the careful individual selection of the former by the latter. Thus the various kinds of ornamental hair (beard, hair of head, etc.), the tint of the face, the peculiar form of the lips, nose, ears, etc., are to be explained, as we find them in man and the male ape; also the brilliant plumage of the humming bird, the bird of paradise, pheasant, etc. I have dealt fully with

these interesting facts in the eleventh chapter of the *History of Creation*, and must refer the reader thereto. I will only point out here how valuable the whole of this chapter of Darwinism is for the understanding of the foundation of species on the one hand and men's fashions and customs on the other. It is most closely connected with ethical problems.

The growth of fashion in civilised life is very important, not only for the development of the sense of beauty and for the sexual selection of the sexes, but also in connection with the origin of the feeling of shame and the finer psychological traits that relate to it. The lower savages have no more sense of shame than animals or children. They are quite naked, and accomplish the sexual act without the slightest trace of shame. The beginning of clothing which we find among the middle savages is not due to a sense of shame, but partly to low temperature (in the polar regions), partly to vanity and love of decoration (such as ornamenting the ears, lips, nose, and sex-organs by the insertion of shells, pieces of wood, flowers, stones, etc.). Afterwards the sense of shame sets in, and we have the covering of certain parts of the body with leaves, girdles, shirts, etc. In most nations the sexual parts are the first to be covered; though some attach importance to the veiling of the face. In many Oriental tribes (especially Mohammedan) it is still the first precept of female chastity to veil the face (the most characteristic part of the individual), while the rest of the body may remain naked. Generally speaking, the æsthetic and psychological relations of the sexes play the chief part in the higher development of morals. Morality is often taken to be synonymous with the law of sexual intercourse.

As the features of civilised life advance, the influence

of reason increases, and so does the power of hereditary tradition and the moral ideas associated with it. The result is a severe conflict between the two. Reason seeks to judge everything by its own standard, to learn the causes of phenomena and direct practical life accordingly. On the other hand tradition, or "good morals," looks at everything from the point of view of our forefathers and other venerable laws and religious precepts. It is indifferent to the independent discoveries of reason and the real causes of things. It demands that the practical life of every individual be framed in accordance with the hereditary morality of the race or State. Thus we get the inevitable conflict between reason and tradition, or science and religion, which continues in our own day. Sometimes in the course of it a "new fashion" is substituted for some sacred tradition, a transitory custom that succeeds in imposing itself by its novelty or curiosity; and when this has contrived to win general acceptance, or has gained the support of Church or State to some extent, it is regarded in much the same light as the older morality.

The lowest races of the present time (for instance, the pithecoid pygmies, the Veddahs of Ceylon, the Akkas of Central Africa) are very little higher than their primate-ancestors in mental development. This is also true of their habits of life and morals. As their ideas are for the most part concrete and sensual, their power of forming abstract concepts is very little developed; they have hardly any religious ideas to speak of. But with the middle savages we begin to find the craving to know the causes of things and the idea of spirits that are concealed behind the phenomena of sense. Dread of these leads to worship, fetichism, and animism, the beginning of religion. Even at this early stage of worship we find

certain customs associated with the cult to which a symbolical or mysterious meaning is given. These ceremonies lead on in the higher races to the great religious festivities, which the Greeks called "mysteries." Sensual images of various kinds are mixed up in them with supersensual ideas and superstitions. The festivals, processions, dances, hymns, and sacrifices of all sorts that form part of the cult are more or less concerned with the mysterious, and are therefore considered "holy." They are often made the pretext of sensual gratifications, which end in gross immorality and orgies.

From the older pagan and Jewish religious usages were afterwards developed in the Christian Church those parts of the cult which are known as sacraments. These miraculous sacraments, by the mysterious action of which man is supposed to be born again or regenerated, very quickly became powerful instruments in the hand of the Church and thorny problems for theologians, especially after Gregory the Great introduced the dogmas of Purgatory and the relieving power of the Mass. According to St. Thomas of Aquin, the sacraments are channels that convey the grace of God to sinful man. The papal authorities fixed their number at seven (baptism, eucharist, penance, confirmation, matrimony, orders, and extreme unction) in the twelfth century. The superstitious content of these sacraments was generally lost sight of in the glamour of their ceremonious side, but their authority was unshaken. Since the Reformation the Protestants have retained only the two chief sacraments which were founded by Christ himself—Baptism and the Lord's Supper.

Christian baptism is a continuation of the older ceremonies of washing and purification that were in use thousands of years before Christ among nations of the east and among the Greeks. They combined the hygienic

value of the bath with the idea of a regeneration of the soul and spiritual purification. Augustine, who founded the dogma of original sin, held that the baptism of children was necessary for the salvation of their souls, and it then became general. It has since given rise to a number of superstitious ideas and unfortunate family troubles, but it is still regarded as a sacred ceremony. Millions of Christians still believe that the child's soul is saved (though it has no consciousness whatever when baptised) and delivered from the power of the devil and the curse of sin by baptism.

The second sacrament that Luther retained is the Lord's Supper, or the sacrament of the body and blood of Christ. It was instituted by Christ on the night before his death, and is a continuation of the paschal supper of the Jews, in which the head of the house shared bread and wine with his family with certain ritual ceremonies. In this paschal supper the people of Israel celebrated their release from the bondage of Egypt and their distinction as the "chosen people." By connecting his "last supper" with the traditional rite of the Jews, Christ sought on the one hand to found the new dispensation on the old, and on the other hand to institute a love-feast (communion or agape) among his followers. Like baptism, the Lord's Supper led afterwards to the bitterest controversy among theologians.

The differences of opinion as to the Eucharist in the Middle Ages culminated at last in the opposition of the two reformers, Luther and Zwingli. The latter, the founder of the Free Reformed Church, saw in the Supper only a symbolical act and a commemoration of Christ. Luther, however, adhered to the mysterious miracle that had been defined in 1215 by the dogma of transubstantiation. Bread and wine are believed on this view to be converted physically into the body and blood of Christ! I was taught this in 1848 by the minister who prepared me for confirmation, and to whom I was greatly attached. We were actually to perceive this change when we assisted at the Supper for the first time, if we did so with real faith. As I was quite conscious of having this quality, I had great expectations of the miracle. But I was very painfully disillusioned when I found only the familiar taste of bread and wine, not the flesh and blood that faith had desired. I had to regard myself (then a boy of fourteen years) as an utterly abandoned sinner, and it was with the greatest difficulty that my parents succeeded in pacifying me over my want of faith.

I have spoken somewhat fully in the seventeenth chapter of the *Riddle* of the view of the papacy and ultramontanism which modern historical and anthropological science leads us to form. No one who has any idea of history and of the metamorphoses of religion can question that Romanism is a miserable caricature of primitive Christianity; it retains the name, but has completely reversed the principles. In the course of

its domination, from the fourth to the sixteenth century, the papacy has raised up the marvellous structure of the Catholic hierarchy, but has departed further and further from the standpoint of pure Christianity. The aim of Romanism is to-day, as it was a thousand years ago, to dominate and exploit a blindly believing humanity. It finds admirable instruments for this in its mystic sacraments, to which it has ascribed an "indelible character." From the cradle to the grave, from baptism to the last anointing, in confirmation and penance, the believer must be reminded that he must live as an obedient and self-sacrificing child; and the sacrament of ordination must teach him that the priest, with his higher inspiration, is the only intermediary between man and God. The symbolical rites that are associated with these sacraments serve to surround them with the magic of the mysterious and exclude the penetration of reason. This is particularly true of the sacrament that has had the greatest practical influence—matrimony.

In view of the extreme importance of the life of the family as a foundation of social and civic life, it is advisable to consider marriage from the biological point of view, as an orderly method of reproduction. Here, as in all other sociological and psychological questions, we must be careful not to accept the present features of civilised life as a general standard of judgment. We have to take a comparative view of its various stages, as we find them among barbarians and savages. When we do this impartially, we see at once that reproduction, as a purely physiological process having for its end the maintenance of the species, takes place in just the same way among uncultivated races as among the anthropoid apes. We may even say that many of the higher animals, especially monogamous mammals and birds, have reached a higher stage than the lower savages; the tender relations of the two sexes towards each other, their common care of their young, and their family-life, have led to the development of higher sexual and domestic instincts, to which we may fitly ascribe a moral character. Wilhelm Bölsche has shown, in his *Life of Love in Nature*, how a long series of remarkable customs has been developed in

the animal world by adaptation to various forms of reproduction. Westermarck has pointed out, in his *History of Marriage*, how the crude animal forms of marriage current among savages have been gradually elevated as we rise to higher races. As the sensual pleasure of generation is combined with the finer psychological feeling of sympathy and psychic attachment, the latter gains constantly on the former, and this refined love becomes one of the richest sources of the higher spiritual functions, especially in art and poetry. Marriage itself, of course, remains a physiological act, a wonder of life, with the organic sex-impulse as its chief foundation. As the conclusion of marriage represents one of the most important moments in human life, we find it accompanied by symbolic ceremonies and festive rites even among lower tribes. The immense variety of marriage festivals shows how this important act has appealed to the imagination. Priests quickly recognised this, and decked out marriage with all kinds of ceremonies and turned it to the advantage of their Church. While the Catholic Church raised it to the status of a sacrament and ascribed to it an "indelible" character, it declared that it was indissoluble when performed according to ecclesiastical rite. This unwholesome influence of Romanism, this dependence of matrimony on religious mysteries and ceremonies, and difficulty of obtaining divorce, etc., still continue in our day. It is only a short time since the German Reichstag, under the influence of the Centre [Catholic] party, added laws to its civic code which increase instead of lessening the difficulty of obtaining divorce. Reason demands the liberation of marriage from ecclesiastical pressure. It demands that matrimony be grounded on mutual love, esteem, and devotion, and that it at the same time be counted a

social contract, and be protected, as civil marriage, by proper legislation. But when the contracting parties find (as so often happens) that they have mistaken each other's character, and that they do not suit each other, they should be free to dissolve the bond. The pressure which comes of marriage being regarded as a sacrament, and which prevents the dissolution of unhappy marriages, is merely a source of vice and crime.

We find in many other features of our social life, besides marriage, a contradiction between the demands of reason and the traditional usages which modern civilisation has taken over as a heritage from earlier and lower nations, and partly from barbarians and savages. In the public life of States this contradiction is much more striking than the private life of the family or the individual. Whereas the milder teaching of the Christian religion—sympathy, love of one's fellows, patience, and devotion—has had a good influence in many ways, there can be no question of this in the international relations of the nations; here we find pure egoism. Every nation seeks to take advantage of others by cunning or force, and, wherever possible, to subjugate them: if they will not consent, the brute force of war is employed. Social misery of all kinds spreads wider and wider, almost in proportion as civilisation developes. Alexander Sutherland is right when he characterises "the leading nations of Europe and their offshoots" (in the United States) as *lower* civilised races. In some respects we are still barbarians.

How far the bulk of modern nations still are from the ideal and the reign of pure reason can be seen by a glance at the social, juridical, and ecclesiastical condition of "these leading nations of Europe," either Teutonic or Latin. We need only consider with an unprejudiced

mind the accounts in our journals of Parliamentary and legal proceedings, Government measures and social relations, in order to realise that the force of tradition and fashion is immense, and resists the claims of reason on every side. This is most clearly seen externally in the power of fashion, especially as regards clothing. There is a good ground for the complaint about "the tyranny of fashion." However unpractical, ridiculous, ugly, and costly a new garment may be, it becomes popular if it is patronised by authority, or some clever manufacturer succeeds in imposing it by specious advertisements. We need only recall the crinoline of fifty years ago, the bustle of twenty years ago, and the exposure of the breast and back by low dresses (with the object of sexual excitement) which was the fashion of forty years ago.[1] For centuries we have had the pernicious fashion of the corset, an article that is as offensive from the æsthetic as from the hygienic point of view. Thousands of women are sacrificed every year to this pitiful fashion, through disease of the liver or lungs; nevertheless, the craze for the hour-glass shape of the female form continues, and the reform of clothing makes little headway. It is just the same with numbers of fashions in the home and in society, of devices in commerce and laws in the State. Everywhere the demands of reason advance little in their struggle with the venerable usages of tradition.

A false sense of honour dominates our social life, just as a false sense of modesty controls our clothing. The true honour of man or woman consists in their inner moral dignity, in the determination to do only what they

[1] At the moment I translate this telegrams from Germany announce that, by the Emperor's orders, a number of ladies were excluded from the opera for not observing this custom.—TRANS.

conceive to be good and right, not in the outer esteem of their fellows or in the worthless praise of a conventional society. Unfortunately, we have to admit that in this respect we are still largely ruled by the foolish views of a lower civilisation, if not of crude barbarians.

In many other features of our life besides this false modesty and false honour we perceive the force of social usage. Many of what are thought to be honourable customs are relics of barbarism; much of our morality is, in the light of pure reason, downright immorality. As even the latter is due to adaptation, and as the same custom may be at one time thought useful and fitting, at another time injurious and bad, we see again that it is impossible to restrict the idea of adaptation to useful variations. We may say the same of the changing rules of education, commerce, legislation, and so on. The ideal in all departments of life is pure reason; but it has to struggle long against the current prejudices and customs, which find their chief support in the superstitions of the Church and the conservative tendencies of the State. In this state of Byzantine immorality, decorating itself so often with the mantle of piety, practical materialism flourishes, while monism, or theoretical materialism, is thrust aside.

If we sum up all that monistic science has taught us as to the origin and development of morality, we may put it in the following series of propositions: 1. By adaptation to different conditions of life the simple plasm of the earliest organisms, the archigonous monera, undergoes certain modifications. 2. As the living plasm reacts on these influences, and the reaction is often repeated, a habit is formed (as in the catalysis of certain inorganic chemical processes). 3. This habit is hereditary, the repeated impressions being fixed in the nucleus (or

caryoplasm) in the case of the unicellulars. 4. When hereditary transmission lasts through many generations, and is strengthened by cumulative adaptation, it becomes an instinct. 5. Even in the protist cœnobia (the cell-communities of the protophyta and protozoa) social instincts are formed by association of cells. 6. The antithesis of the individual and social instinct, or of egoism and altruism, increases in the animal kingdom in proportion to the development of psychic activity and social life. 7. In the higher social animals definite customs arise in this way, and these become rights and duties when obedience to them is demanded by the society (herd, flock, people) and the breach of them punished. 8. Savage races at the lowest stage, without religion, are not differently related to their customs than the higher social animals. 9. The higher savages develop religious ideas, combine their superstitious practices (fetichism and animism) with ethical principles, and transform their empirical moral laws into religious commands. 10. Among barbaric, and more particularly among civilised, races definite moral laws are formed by the association of these hereditary religious, moral, and legal ideas. 11. In the civilised races the Church formulates the religious commands, and jurisprudence the legal commands, in more definitely-binding forms; the advancing mind remains, however, subject in many respects to Church and State. 12. In the higher civilised nations pure reason gains more and more influence on practical life, and thrusts back the authority of tradition; on the basis of biological knowledge a rational or monistic ethic is developed.

## Chapter XIX.

## DUALISM

Dualistic systems of Kant I. and Kant II. His antinomies. Cosmological dualism. The two worlds. The world of bodies and the world of spirits. Truth and fiction. Goethe and Schiller. Realism and idealism. Anti-Kant. Law of substance. Attributes of substance. Sensation and energy. Passive and active energy. Trinity of substance: matter, force, and sensation. Constancy of sensation. Psyche and physics. Reconciliation of principles.

The history of philosophy shows how the mind of man has pressed along many paths during the last two thousand years in pursuit of truth. But, however varied are the systems in which its efforts have found embodiment, we may, from a general point of view, arrange them all in two conflicting series—Monism, or the philosophy of unity; and Dualism, or the philosophy of the duality of existence. Lucretius and Spinoza are distinguished and typical representatives of monism; Plato and Descartes the great leaders of dualism. But besides the consistent thinkers of each school there are a number of philosophers who vacillate between the two, or who have held both views at different periods of life. Such contradictions represent a personal dualism on the part of the individual thinker. Immanuel Kant is one of the most famous instances of this class; and as his critical philosophy has had a profound influence, and I was compelled to contrast my chief conclusions with those of Kant, I must once more deal briefly with his

ideas. This is the more necessary as one of the ablest of the many attacks on the *Riddle*, the *Kant Against Haeckel* of Erich Adick of Kiel, belongs to this school.

In the *Creed of Pure Reason*, which I published as an appendix to the popular edition of the *Riddle* in 1903, I pointed out, in view of this and similar Kantist criticisms, the clear inconsistency of the great evolutionary principles of Kant, the natural philosopher, with the mystic teaching which he afterwards made the foundation of his theory of knowledge, and that is still greatly esteemed. Kant I. explained the constitution and the mechanical origin of the universe on Newtonian principles, and declared that mechanicism alone afforded a real explanation of phenomena; Kant II. subordinated the mechanical principle to the teleological, explaining everything as a natural design. Kant I. convincingly proved that the three central dogmas of metaphysics—God, freedom, and immortality—are inacceptable to pure reason. Kant II. claimed that they are necessary postulates of practical reason. This profound opposition of principles runs through Kant's whole philosophic work from beginning to end, and has never been reconciled. I had already shown in the *History of Creation* that this inconsistency has a good deal to do with Kant's position in regard to evolution. However, this radical contradiction of Kant's views has been recognised by all impartial critics. It has lately been urged with great force by Paul Rée in his *Philosophy* (1903). We need not, therefore, linger in proving the fact, but may go on to consider the causes of it.

A subtle and comprehensive thinker like Kant was naturally perfectly conscious of the existence of this inconsistency of his dualistic principles. He endeavoured to meet it by his theory of antinomies, declaring that

pure reason is bound to land in contradictions when it attempts to conceive the whole scheme of things as a connected totality. In every attempt to form a unified and complete view of things we encounter these unsolvable antinomies, or mutually contradictory theses, for both of which sound proof is available. Thus, for instance, physics and chemistry say that matter must consist of atoms as its simplest particles; but logic declares that matter is divisible *in infinitum*. On the one theory time and space are infinite; on the other theory, finite. Kant attempted to reconcile these contradictions by his transcendental idealism, by the assumption that objects and their connection exist only in our imagination, and not in themselves. In this way he came to frame the false theory of knowledge which is honoured with the title of "criticism," while as a matter of fact it is only a new form of dogmatism. The antinomies are not explained by it, but thrust aside; nor was there more truth in the assertion that equal proof is available for theses and antitheses.

The famous work of Kant's earlier years, *The General Natural History and Theory of the Heavens* (1755), was purely monistic in its chief features. It embodied a fine attempt "to explain the constitution and mechanical origin of the universe on Newtonian principles." It was mathematically established forty years afterwards by Laplace in his *Exposition du système du monde* (1796). This fearless monistic thinker was a consistent atheist, and told Napoleon I. that there was no room for "God" in his *Mecanique céleste* (1799). Kant, however, afterwards found that, though there was no rational evidence of the existence of God, we must admit it on moral grounds. He said the same of the immortality of the soul and the freedom of the will. He then constructed

a special "intelligible world" to receive these three objects of faith; he declared that the moral sense compelled us to believe in a supersensual world, although pure theoretical reason is quite unable to form any distinct idea of it. The categorical imperative was supposed to determine our moral sense and the distinction between good and evil. In the further progress of his ethical metaphysics Kant expressly urged that practical reason should take precedence of theoretical—in other words, that faith is superior to knowledge. In this way he enabled theology and irrational faith to find a place in his system and claim supremacy over all rational knowledge of nature.

The older Greek philosophy had been purely monistic, Anaximander and his disciple Anaximenes (in the sixth century B.C.) conceiving the world in the sense of our modern hylozoism, but Plato introduced (200 years afterwards) the dualistic view of things. The world of bodies is real, accessible to our sensible experience, changeable and transitory; opposed to it is the world of spirits, only to be reached by thought, supersensual, ideal, immutable, and eternal. Material things, the objects of physics, are only transient symbols of the eternal ideas, which are the subject of metaphysics. Man, the most perfect of all things, belongs to both worlds; his material frame is mortal, the prison of the immortal and invisible soul. The eternal ideas are only embodied for a time in the world of bodies here below; they dwell eternally in the world of spirits beyond, where the supreme idea (God, or the idea of the good) controls all in perfect unity. The human soul, endowed with free-will, is bound to develop the three cardinal virtues (wisdom, fortitude, and prudence) by the cultivation of its three chief moral faculties (thought, courage,

and zeal). These fundamental principles of Plato's teaching, systematically presented by his pupil Aristotle, met with a very general acceptance, as they could easily be combined with the teaching of Christianity which arose 400 years afterwards. The great majority of later philosophic and religious systems followed the same dualistic paths. Even Kant's metaphysics is only a new form of it; only its dogmatic character is hidden by the ascription to it of the convenient title of the "critical" system.

Modern science has opened out to us immense departments of the real world that are accessible to observation and rational inquiry; but it has not taught us a single fact that points to the existence of an immaterial world. On the contrary, it has shown more and more clearly that the supposed world beyond is a pure fiction, and only merits to be treated as a subject for poetry. Physics and chemistry in particular have proved that all phenomena that come under our observation depend on physical and chemical laws, and that all can be traced to the comprehensive and unified law of substance. Anthropogeny has taught us the evolution of man from animal ancestors. Comparative anatomy and physiology have shown that his mind is a function of the brain, and his will not free; and that his soul, absolutely bound up with its material organ, passes away at death like the souls of other mammals. Finally, modern cosmology and cosmogony have found no trace whatever of the existence and activity of a personal and extra-mundane God. All that comes within the range of our knowledge is a part of the material world.

In his observations on the supersensual world Kant lays stress on the fact that it lies beyond the range of experience, and is known only by faith. Conscience, he

thinks, assures us of its existence, but does not give us any idea of its nature; and so the three central mysteries of metaphysics are mere words without meaning. But, as nothing can be done with mere words, Kant's followers have attempted to put a positive substance into them, generally in relation to traditional ideas and religious dogmas. Not only orthodox Kantians, but even critical philosophers like Schleiden, have dogmatically asserted that Kant and his disciples have established the transcendental ideas of God, freedom, and immortality, just as Kepler, Newton, and Laplace established the laws of celestial motion. Schleiden imagined that this dogmatic affirmation would refute "the materialism of modern German science." Lange has shown, on the contrary, that such dogmatism is utterly foreign to the spirit of the *Critique of Pure Reason*, and that Kant held the three ideas to be quite incapable of either positive or negative proof, and so thrust them into the domain of practical philosophy. Lange says: "Kant would not see, as Plato would not see before him, that the intelligible world is a world of poetry, and has no value except in this respect." But if these ideas are mere figments of the poetic imagination, if we can form neither positive nor negative idea of them, we may well ask: What has this imaginary spirit-world to do with the pursuit of truth?

As I have raised the question of the limits of truth and fiction, I may take the opportunity of pointing out the general importance of this distinction. Undoubtedly man's knowledge is limited, from the very nature of our faculties or the organisation of our brain and sense-organs. Hence, Kant is right when he says that we perceive only the phenomena of things, and not their inner essence, which he calls the "thing in itself." But he is wrong and

altogether misleading when he goes on to doubt the reality of the external world, and says it exists only in our presentations—in other words, that life is a dream. It does not follow, from the fact that our senses and phronema can reach only a part of the properties of things, that we call into question their existence in time and space. But our rational craving for a knowledge of causes impels us to fill up the gaps in our empirical knowledge by our imagination, and thus form an approximate idea of the whole. This work of the imagination may be called "fiction" in a broad sense—hypotheses when they are in science, faith when they belong to religion. However, these imaginative constructions must always take a concrete form. As a fact, the imagination that constructs the ideal world is never content merely to assume its existence, but always proceeds to form an image of it. But these forms of faith have no theoretical value for philosophy if they contradict scientific truth, or profess to be more than provisional hypotheses; otherwise they may be of practical service, but are theoretically useless. Hence we fully recognise the great ethical and pædagogical value of poetry and myths, but are by no means disposed to give them precedence of empirical knowledge in our quest of the truth. I agree entirely with the excellent criticism of Kant which Albert Lange gives in his *History of Materialism* (vol. ii.); but I am unable to follow him when he transfers his idealism from practical to theoretical questions, and urges the erroneous theory of knowledge derived from it in opposition to monism and realism. It is true that, as Lange says,

> Kant did not lack the sense for the conception of this intelligible world (as an imaginative world); but his whole education and the period in which his mental life developed prevented him from indulging it. As he was

denied the liberty of giving a noble form, free from all medieval distortion, to the vast structure of his ideas, his positive philosophy was never fully developed. His system, with its Janus-face, stands at the limit of two ages. He himself, in spite of all the defects of his deductions, is a teacher of the ideal. Schiller especially has grasped with prophetic insight the very essence of his teaching, and purified it of its scholastic dross. Kant held that we must only think, not see, the intelligible world; though what he thinks must have objective reality. Schiller has rightly brought the intelligible world visibly before us by treating it as a poet, and thus following in the footsteps of Plato, who, in contradiction to his own dialectic, reached his highest thought when he allowed the supersensual to become a thing of sense in the myth. Schiller, the poet of freedom, dared to carry freedom openly into the land of dreams and of shadows; then there arose under his hand the dreams and shadows of the ideal.

In view of the great influence that Schiller's idealism has had in the spread of Kant's practical moral philosophy, we may for a moment consider it in contrast with the realistic views of Goethe.

The profound opposition of the views of the two greatest poets of the classical period of German literature is rooted deep in their natures. This has been proved so often and so thoroughly, and has so frequently been represented as the complementary quality of the two poets, that I need merely recall it here. As for Goethe, I have, in my *General Morphology*, shown his historical importance in connection with the theory of evolution and the system of monism. With all his versatile occupations, this great genius found time to devote to the morphological study of organisms, and to establish his comprehensive biological theories on this empirical basis. His discovery of the metamorphosis of plants and his vertebral theory of the skull justify us in classifying him as one of the chief forerunners of Darwin. When I dealt with this in the fourth chapter of the *History of Creation*, I pointed out how great an influence these morphological studies, together with his idea of

evolution, had on the realism of his philosophy. They led him direct to monism and to an admiration of Spinoza's monistic pantheism. Schiller had neither great interest nor clear insight for these studies. His idealistic philosophy disposed him rather to Kant's dualistic metaphysics and to an acceptance of the three central mysteries—God, soul, and freedom. Both Schiller and Goethe had a thorough knowledge of anthropology and psychology. But the anatomic and physiological studies that Schiller made as a military surgeon had very little influence on his transcendental idealism, in which the ethical-æsthetic element preponderated. On the other hand, Goethe's empirical realism was profoundly influenced by his medical studies at Strassburg, and especially by his later comparative anatomical and botanical investigations at Jena and Weimar.

The philosophic antithesis which we thus find in the biological foundations of the views of Goethe and Schiller represents to an extent the Janus-face that the philosophic genius of the German people bears to our own day. Goethe, the realist, penetrated deep into the empirical study of the material world, and sought, with Spinoza, to establish the unity of the universe. Schiller, the idealist, lives rather in the spirit world, and seeks, with Kant, to utilise its ethical ideals—God, freedom, and immortality—for the education of the human race. Both tendencies of thought have led the genius of Germany—like the genius of Greece 2,000 years ago—to a great number of vast intellectual achievements. Goethe wrought the ideal in his practical life, Kant discovered it, Schiller proclaimed it to be the fittest aim of the future.

It is wrong to conclude from isolated quotations from

Goethe that he occasionally betrayed the dualism of Schiller in his opinions. Some of the remarks in this connection that Eckermann has left us from his conversations with Goethe must be taken very carefully. Generally speaking, this source is not reliable; many of the observations that the mediocre Eckermann puts into the mouth of the great Goethe are quite inconsistent with his character, and are more or less perverted. Hence, when recent high-placed orators declare at Berlin that Goethe saved the high ideals of God, freedom, and immortality, like Schiller, and thus borrow a certain support for their Christian belief, they only show how little they have grasped the profound antithesis of the views of the two poets. Goethe notoriously described himself as a "renegade non-Christian." The creed of the "great heathen" Goethe, as we find it in *Faust* and *Prometheus* and *God and the World*, and a hundred other magnificent poems, is pure monism, of the pantheistic character which we take to be alone correct—hylozoism; he is equally far from the one-sided materialism of Holbach or Carl Vogt and the extreme dynamism of Leibnitz and Ostwald. Schiller by no means shared this realistic view of things; his idealistic sense fled beyond nature into the spirit world. However, our theoretic hylozoism does not exclude practical idealism, as Goethe's whole life showed. On the other hand, princes and priests often let us see how easily theoretical idealism goes with practical materialism, or hedonism.

In the month of February, 1904, the centenary of the death of Kant was celebrated throughout the world of culture. In numbers of academic speeches and writings he was greeted as the greatest thinker of Germany. He died on the same day (February 12) on which Darwin was born five years later. It is unquestionable that Kant has

had an immense influence on the whole development of German philosophy. But while recognising his extraordinary genius, we must not be blind to the glaring contradictions and defects of his dualist system. From the monistic point of view, we can only regard his profound influence during the whole of the nineteenth century as mischievous. Most certainly he had a quite exceptional talent for philosophic speculation and penetrating thought, and he added to his great mental qualities a blameless character and an undeniable sense of truth in life (though not in thought). It was a serious misfortune for Kant and for the philosophic school he led that his education prevented him from acquiring a thorough knowledge and correct conception of the real world. Shut up throughout life within the narrow bounds of his native town, Königsberg, he never travelled beyond the frontier of Prussia, and so did not obtain that knowledge of the world that comes of travelling. In the study of nature he confined himself to the physics of the inorganic world, in the study of man to the immortal soul. At the close of his university studies Kant had to earn his living as a house-teacher for nine years (from twenty-two to thirty-one), just at the most important period of his life, in which the independent development of the personal and scientific character is decided when the academic studies are over.

In such adverse circumstances of mental adaptation a deep mystic trait, which had been inherited from pious parents and confirmed by the strictly religious training of his early years, was fixed in Kant's character. Hence it was that faith in the three central mysteries came upon him more and more in later years: he gave them precedence over all the attainments of theoretical reason while granting that we can form neither a negative nor

positive idea of them. But how can the belief in God, freedom, and immortality determine one's whole view of life as a postulate of practical reason, if we cannot form any definite idea of them?

Every philosophy that deserves the name must have clear ideas as the bases of its thought-structure; it must have definite views in connection with its fundamental conceptions. Hence most of Kant's followers have not been content to follow his direction merely to *believe* in the three central mysteries; they have sought to associate definite mental pictures with the empty concepts of God, freedom, and immortality. In this they have drawn upon the religious imagination, and have passed from the real knowledge of nature into the transcendental realm of poetry. Monism, based on this real knowledge of nature, has to keep clear of such dualism.

The extraordinary glorification of Kant that took place on the occasion of his centenary must have seemed strange to many scientists who recognise in his idealism one of the greatest hindrances to the spread of the modern monistic philosophy of nature. But it is not difficult to explain this. We must remember, in the first place, the contradictory views that are embodied in Kant's system; everyone could find in Kant's works something to correspond to his own convictions—the monistic physicist could read of the mechanical sway of natural law throughout the whole knowable world, and the dualistic metaphysician of the free play of the divine aim in the spiritual world. The physician and physiologist would note with satisfaction that in his criticism of pure reason Kant had been unable to find any evidence for the existence of God, the immortality of the soul, or the freedom of the will. The jurist and theologian would find with equal gratification that in the practical reason Kant claims

these three central dogmas as necessary postulates. I have shown to some extent, in the sixth chapter of the *Riddle*, how these irreconcilable contradictions in Kant's system are due to a psychological metamorphosis.

It is just these very contradictions, which run through Kant's philosophy from beginning to end, that maintain its popularity. Educated people who desire to form a view of life rarely read Kant's difficult (and often obscure) works in the original, but are content to learn from extracts, or from a history of philosophy, that the Königsberg thinker succeeded in squaring the circle, or in reconciling natural science with the three central dogmas of metaphysics. The "higher powers," who are particularly concerned to save the latter, favour the teaching of Kant's dogmas, because it closes the way to real explanation and prevents independent thinking. This is especially true of the ministers of public instruction in the two chief German States—Prussia and Bavaria. In their open attempt to subordinate the school to the Church, they desire, above all, the primacy of practical reason—that is to say, the subjection of pure reason to faith and revelation. In German universities to-day belief in Kant is a sort of ticket of admission to the study of philosophy. The reader who would realise the pernicious effect of this official faith in Kant on the advance of scientific knowledge will do well to read the able criticism in the brilliant posthumous work of Paul Rée.

In the face of the dualism which still prevails in the academic teaching of philosophy (especially in Germany), we must base our monistic system on the universality of the law of substance. This harmoniously combines the laws of the conservation of matter and of energy. As I have fully explained my own conception of this law in

the twelfth chapter of the *Riddle*, I will only say here that its validity is quite independent of any particular theory of the relations of matter and force.[1] The materialism of Holbach and Büchner lays a one-sided stress on the importance of matter: the dynamism of Leibnitz and Ostwald on that of force. If we avoid these extremes, and conceive matter and force as inseparable attributes of substance, we have pure monism, as we find it in the systems of Spinoza and Goethe. We might then substitute for the word "substance," as Hermann Cröll does, the term "force-matter." The further question as to the correctness of any particular physical conception of matter is quite independent of this.

The two knowable attributes or inalienable properties of substance, without which it is unthinkable, were described by Spinoza as extension and thought; we speak of them as matter and force. The "extended" (or space-occupying) is matter; and in Spinoza "thought" does not mean a particular function of the human brain, but energy in the broadest sense. While hylozoistic monism conceives the human soul in this sense as a special form of energy, the current dualism or vitalism affirms, on the authority of Kant, that psychic and physical forces are essentially different; that the former belong to the immaterial and the latter to the material world. The theory of psycho-physical parallelism, as developed especially by Wundt (1892), gives a very sharp and definite expression to this dualism; it says that "physical processes correspond to every psychic phenomenon, but the

[1] The English reader will find in this a reply to the foolish notion circulated in this country that the recent discovery of radio-action and the composition of the atom from electrons has affected Haeckel's position. His monism is completely indifferent to changes in the physicist conception of the nature of matter.—TRANS.

two are completely independent of each other and have no natural causal connection."

This widespread dualism finds its chief support in the difficulty of directly connecting the processes of sensation with those of movement; and so the one is regarded as a psychic and the other as a physical form of energy. The conversion of the outer stimulus (waves of light, sound, etc.) into an inner sensation (sight or hearing) is regarded by monistic physiology as a conversion of force, a transformation of photic or acoustic energy into specific nerve-energy. The important theory of the specific energy of the sensory nerves, as formulated by Johannes Müller, forms a bridge between the two worlds. But the idea which these sensations evoke, the central process in the thought-organ or phronema that brings the impressions into consciousness, is generally regarded as an incomprehensible mystery. However, I have endeavoured to prove, in the tenth chapter of the *Riddle*, that consciousness itself is only a special form of nervous energy, and Ostwald has lately developed the theory in his *Natural Philosophy*.

The processes of movement which we observe in every change of one form of energy into another, or every passage of potential into actual energy, are subordinate to the general laws of mechanics. The dualist metaphysic has rightly said that the mechanical philosophy does not discover the inner causes of these movements. It would seek these in psychic forces. On our monistic principles they are not immaterial forces, but based on the general sensation of substance, which we call *psychoma*, and add to energy and matter as a third attribute of substance.

The difficulty of combining our monism with Spinoza's doctrine of substance is met by detaching the idea of

energy from sensation and restricting it to mechanics, so as to make movement a third fundamental property of substance with matter (the "extended") and sensation (the "thinking"). We may also divide energy into active (= will in the sense of Schopenhauer) and passive (= sensation in the broadest sense). As a matter of fact, the energy to which modern energism would reduce all phenomena has not an independent place in Spinoza's system besides sensation; the attribute of thought (the psyche, soul, force) comprises the two. I am convinced that sensation is, like movement, found in all matter, and this trinity of substance provides the safest basis for modern monism. I may formulate it in three propositions: (1) No matter without force and without sensation. (2) No force without matter and without sensation. (3) No sensation without matter and without force. These three fundamental attributes are found inseparably united throughout the whole universe, in every atom and every molecule. In view of the great importance of this view for our hylonistic system of monism, it may be well to consider each of these three attributes in connection with the law of substance.

*A.* MATTER.—As extended substance, matter occupies infinite space, and each individual body forms a part of the universe as real substance. The law of the conservation of matter teaches us that the sum of matter is eternal and unchangeable. This applies equally to the various kinds of matter which we call the chemical elements, or ponderable matter, and to the ether that fills the spaces between the atoms and molecules, or imponderable matter. The mischievous depreciation of matter (and the consequent disdain of materialism) and its antithesis to "spirit" is partly due to the use of such phrases as "raw" and "dead" matter, and partly to the

deep-rooted mysticism we have inherited from barbaric ancestors, and find it hard to shake off.

*B.* Energy.—All parts of the substance that fills infinite space are in constant and eternal motion. Every chemical process and every physical phenomenon is accompanied by a change in the position of the particles which compose the matter. The law of the conservation of energy teaches us that the sum of force or energy that is ever at work in the universe is unchangeable. In the formation or decomposition of a chemical compound the particles of matter move about, and so in every mechanical, thermic, electric, and other process. The changes that take place depend on a constant change of force, both in organic and inorganic bodies; one form of force is converted into another without a particle of the whole being lost. This law of the conservation of force has lately been called, as a rule, the conservation of energy (or the principle of energy), since the ideas of force and energy have been more clearly distinguished in physics; energy is now usually defined as the product of force and direction. It must be noted, however, that the word "energy" (as an equivalent to "work" in the physical sense) is still used in many different senses, as is also the word "force." Others define energy as "work, or all that comes of work and may be converted into work." One particular school of voluntarism (Wundt) reduces the motive-force of energy to will. Crusius said in 1744: "Will is the dominating force in the world." And Schopenhauer defines the world (or substance) as "will and presentation."

*C.* Sensation.—In describing sensation (in the broadest sense) as a third attribute of substance, and separating "sensitive substance" from energy as "moving substance," I rely on the observations I made

and look out on the whole mental life of humanity, we see through all its continuous development the constancy of the psychoma, which has its roots in the sensations of each individual. This highest achievement of the work of the plasm in the human brain was, however, first developed in the sensations of the lower animals, and these are in turn connected by a long series of evolutionary stages with the simpler forms of sensation that we find in the inorganic elements, and that reveal themselves in chemical affinity. Albrecht Rau expressly says in his excellent *Sensation and Thought* (1896) that "perception or sensation is a universal process in nature. This involves, moreover, the possibility of reducing thought itself to this universal process." Recently Ernst Mach has said, in his *Analysis of Sensation and the Relation of the Physical to the Psychical*, that "sensations are the common elements of all possible physical and psychic occurrences, and consist simply in the different mode of the combination of the elements and their dependence on each other." It is true that Mach, in his one-sided emphasis of the subjective element of sensation, goes on to form a similar psychomonism to that of Verworn, Avenarius, and other recent dynamists; but the fundamental character of his system is purely monistic, like the energism of Ostwald.

In thus uniting sensation with force and matter as an attribute of substance, we form a monistic trinity, and are in a position to do away with the antitheses that are rigidly maintained by dualists between the psychic and the physical, or the material and the immaterial world. Of the three great monistic systems materialism lays too narrow a stress on the attribute of matter, and would trace all the phenomena of the universe to the mechanics of the atoms or to the movements of their

ultimate particles. Spiritualism, with equal narrowness, builds on the attribute of energy; it would either explain all phenomena by motor forces or forms of energy (energism), or reduce them to psychic functions, to sensation or psychic action (panpsychism). Our system of hylonism (or hylozoism) avoids the faults of both extremes, and affirms the identity of the psyche and the physis in the sense of Spinoza and Goethe. It meets the difficulties of the older theory of identity by dividing the attribute of thought (or energy) into two co-ordinate attributes, sensation (psychoma) and movement (mechanics).

## Chapter XX.

# MONISM

Defence of monism. Pure and applied science (theoretic and practical reason). Pure (theoretical) sciences: physics, chemistry, mathematics, astronomy, geology—Biology, anthropology, psychology, philology, history. Applied (practical) sciences; medicine, psychiatry, hygiene, technology, pædagogics, ethics, sociology, politics, jurisprudence, theology. Antinomy of the sciences. Rational and dogmatic disciplines. Correlation of the sciences. Faculties. Reform of education. The ideal world. Harmony of monism.

Now that we have reached the end of our long journey, we may take a general survey of the path we have pursued, and say how far we owe our progress to the monistic philosophy. In doing so, we shall at once justify our own point of view and indicate the relation of biology to the other sciences. I feel the more bound to do this as the present volume is not only a necessary supplement to the *Riddle*, but at the same time my last philosophic work. At the end of my seventieth year I would supply some of the defects of the *Riddle*, answer some of the most stringent criticisms directed against it, and as far as possible complete the philosophy of life at which I worked for half a century.

In inviting my readers to accompany me once more through the broad domain of the monistic philosophy I must, as their modest guide, show scientific justification at the narrow entrance—produce, so to say, the ticket of admission to this investigation. The academic philosophy which still controls the German universities

watches every door with jealous eyes, and has an especial concern to keep out modern biology. Official German philosophy is still for the most part taken up with a medieval metaphysic and the dualism of Kant, the openly dogmatic character of which it greets as "criticism." In the course of the forty years during which I have taught as ordinary professor of zoology at Jena I have had occasion to assist at several hundred examinations of doctors, teachers, etc., in which distinguished representatives of philosophy were examiners. I saw that nearly always the chief stress was laid on a kind of conceptual gymnastics and self-observation, and on the correct knowledge of the innumerable errors which the (mainly dualistic) leaders of ancient and modern philosophy have left us in their vast literature. The central feature of the whole scheme is Kant's theory of knowledge, the defects and one-sidedness of which I have treated in the first and the nineteenth chapters. In psychology a most extensive knowledge of psychic powers on the basis of the introspective method is demanded; the physiological analysis of the "soul" and the anatomic study of the phronema are carefully avoided, as are also the comparative and genetic study of the mind. Many of our metaphysicians go even farther and regard philosophy as a separate science—a sublime "mental science," quite independent of the common empirical sciences. One is tempted to quote the saying of Schopenhauer: "It is a sure sign of a philosopher that he is not a professor of philosophy." In my opinion, every educated and thoughtful man who strives to form a definite view of life is a philosopher. As queen of the sciences, philosophy has the great task of combining the general results of the other sciences, and of bringing their rays of light to a focus as in a concave mirror. The various tendencies of

thought that arise in such numbers have all a right to scientific respect and discussion, the monistic minority no less than the dualistic majority. We have to inquire, then, how far monism has succeeded in gaining firm foot-hold in the various fields of science, and we may begin with a distinction between pure (theoretical) and applied (practical) science.

Pure philosophy aims at a knowledge of the truth by means of pure reason, as I explained in the first chapter. However, this theoretical philosophy finds itself in most of the sciences in direct and frequently important relations to practical life, and so in the form of applied philosophy becomes a weighty factor in civilisation. In this the real claims of practical life are often in contradiction to the ideal tenets of the scientifically grounded theory. In such cases, in my opinion, the pure pursuit of the truth must take precedence of applied philosophy. I thus dissent entirely from the view of Kant, who expressly gives precedence to practical reason, and subordinates theoretical reason to it. Kant's error was fated to have a terrible influence, because the dominant authorities in Church and State eagerly embraced it to ensure everywhere the supremacy of the dogmas of practical reason over the attainments of pure critical reason.

From the point of view of natural monism we may take physics in the wider sense as the fundamental science. The term *physis* (the Greek equivalent of the Latin " nature "), in its original meaning, comprises the whole knowable world—Kant's *mundus sensibilis*. His supersensual or " intelligible " world is, on his own definition, the object of faith, not knowledge. It is very remarkable to find a thinker like Kant contradicting himself already in his fundamental distinction of the two worlds. How can the supersensual world, with its

three central mysteries (God, freedom, and immortality), be described as intelligible (*i.e.*, knowable), when it is proved by pure reason that the human mind is incapable of knowing it, or of forming any positive or negative idea of it? *Lucus a non lucendo!* We may, therefore, leave this supernatural metaphysical world to faith and fiction, and confine our studies to the real physical world, nature. The idea of physics as a comprehensive natural philosophy, as it was conceived in classic Greece, has been more and more restricted in the course of time. To-day it is generally taken to mean the science of the phenomena of inorganic nature, their empirical determination by observation and experiment (experimental physics), and their reduction to fixed natural laws and mathematical formulæ (theoretical or mathematical physics). Of late, a distinction has been drawn between the physics of mass and the physics of ether; the one deals with mechanics, the movement and equilibrium of ponderable matter, of solid, fluid, and gaseous bodies (statics and dynamics, gravitation, acoustics, meteorology); the other is occupied with the phenomena of ether (or imponderable matter) and its relations to mass (electricity, galvanism, magnetism, optics, and calorics). In all these branches of inorganic physics the monistic view is now generally received, and all attempt at dualistic explanation abandoned.

The vast department of chemistry, which has now become so important both for theoretical and practical purposes, is really only a part of physics. But while modern physics restricts itself to the study of inorganic forms of energy and their conversions, chemistry, as the science of matter, takes up the study of the qualitative differences between the various kinds of ponderable matter. It divides ponderable bodies into some seventy-

eight elements, the relations of which to each other have been determined in the periodic system of the elements, and their probable common origin from some primitive matter (prothyl) been shown. The constant features of chemical combinations which have been established by the analysis and synthesis of the elements, and especially the law of simple and multiple proportions discovered in 1808, led to the empirical determination of the atomic weight of the elements and to the chemical theory of the atom. The acceptance of these atoms (as space-filling separate particles of matter—however we may regard them in other respects) is an indispensable hypothesis in chemistry, like the hypothesis of the molecule in physics. Modern dynamism (or energism) is wrong when it thinks it can dispense with these hypotheses and replace the atoms by the notion of immaterial non-spatial points of force. However, in both the dynamic and the material school monism is retained in every department of chemistry.

Modern science considers the ultimate aim of all research to be the exact determination of phenomena in measure and number, or the reduction of all general knowledge to mathematically formulated laws. As the great Laplace established his system mathematically, it has lately been claimed that a comprehensive (ideal) Laplace-mind could embrace the whole past, present, and future of the universe in a single gigantic mathematical formula. Kant has expressed this exaggerated estimate of mathematics in the phrase: "Every science is only true science in proportion as it is amenable to mathematical treatment"; and to this he has added the second error that the mathematical axioms (being necessary and universal truths) belong to the *à priori* constitution of the mind, and are independent of experience (*à posteriori*).

However, John Stuart Mill and others have shown that the fundamental ideas of mathematics are acquired originally, like those of any other science, by abstraction from experience; and the modern phylogeny of the mind has confirmed this empirical view. We must remember, moreover, that mathematics deals only with quantitative relations in time and space, and not with the qualitative features of bodies. In fact, Kant himself showed that mathematics only answers for the absolute *formal* correctness of conclusions it draws from given premisses, and has no influence on the premisses themselves. Hence, when we examine the abstract thinking-power of the phronema in its mathematical operations physiologically and phylogenetically, we find that even this "exact fundamental science" is only accessible to pure monism and excludes all dualism. The great regard which mathematics enjoys as an exact science in all branches of knowledge is chiefly due to its *formal accuracy*, and to the possibility of expressing infallibly spatial and time-quantities in number and mass.

Astronomy is one of the older sciences that took definite shape thousands of years ago, and received a solid mathematical foundation. Observations of the movements of the planets and eclipses of the sun were conducted by the Chinese, Chaldeans, and Egyptians several thousand years before Christ. Christ himself had no more suspicion of these great cosmological discoveries than of the systems which the Greek natural philosophers had built up 300–600 years before his birth. After Copernicus had destroyed the geocentric system in 1543, and Newton had provided a mathematical basis for the new heliocentric system by his theory of gravitation in 1686, cosmogony was firmly established in a monistic sense by the *General Natural History of the*

*Heavens* of Kant, and the *Mécanique Céleste* of Laplace. Since that time there has been no question of the conscious action of a Creator in any part of astronomy. Astrophysics has enlarged our knowledge of the physical features, and astrochemistry (by means of spectrum analysis) of the chemical nature of the other heavenly bodies. The monism of the physical universe has now been established.

Geology was not developed into an independent science until towards the end of the eighteenth century, and did not extinguish the earlier notion of the creation of the earth until after 1830, when the principle of continuity and evolution was established. The oldest part of the science is mineralogy; the great practical value of the rocks, and especially the metals obtained from them, having appealed to man's interest thousands of years ago. In the stone age, bronze age, iron age, etc., the material for weapons and tools was provided by stone and metal. Afterwards the development of mining led to a closer acquaintance with these metals. But no notice was taken of the fossil remains of animals and plants until the close of the Middle Ages. It was not until the eighteenth century that students began to perceive the great significance of these "creation-medals," and at the beginning of the nineteenth paleontology arose as an independent science, and proved equally important to geology and biology. Other branches of geology, such as crystallography, have also made considerable progress during the last half century, with the aid of physics and chemistry. All these sections of geology, especially geogeny, or the science of the natural development of the earth, are now recognised to be purely monistic sciences.

In the five branches of science I have enumerated

pure monism has been universally and exclusively admitted (as far as they relate to inorganic nature) in the second half of the nineteenth century. There is no question in them to-day of the wisdom and power of the Creator. This is equally true of geology, astronomy, mathematics, chemistry, and physics. It is otherwise with the remaining sciences which deal with organic nature; in these we have not yet succeeded in giving a physical explanation and mathematical formulation of all phenomena. Hence vitalism enters with its dualistic notions, and splits the science into two different branches —natural science (physics in the wider sense) and mental science (metaphysics); fixed natural laws are supposed to rule only in the former, while in the latter we still have the "freedom" of the spirit and the supernatural. This applies, first of all, to biology in the broadest sense (including anthropology and all the sciences that relate to man). In the preceding chapters of biological philosophy we have sought to refute vitalism in every form, and to secure the exclusive acceptance of monism and mechanicism in every branch of the science of life.

Anthropology is still, as it has been for centuries, taken in many different senses. In the widest sense, it embraces the whole vast science of man, just as zoology (in my opinion) deals with all parts of the animal world. Since I regard anthropology as a part of zoology, I naturally extend the principles of monism to both. However, this general monistic conception of the science of man has met with only a restricted acceptance up to the present. As a rule, the term "anthropology" is restricted to the natural history of man, which includes the anatomy and physiology of the human organism, embryology, pre-historic research, and a small part of psychology. But this "official anthropology," as most

of our anthropological societies (especially in Germany) conceive it, generally excludes phylogeny, the greater part of psychology, and all the mental sciences, which are regarded as metaphysical in the narrower sense. I endeavoured to show in my *Anthropogeny* thirty years ago that man (as a placental mammal of the order of primates) is no less unified an organism (with body and soul) than any other vertebrate, and that, therefore, every aspect of his being should be dealt with monistically.

As is well known, the views of experts and laymen alike are very much divided as to the place of psychology in the scheme of the sciences. The great majority of the professional psychologists, and of educated people generally, adhere still to the antiquated dogma, with its religious foundation, that man's soul is immortal and an independent immaterial entity. This dualistic view has been supported in the schools especially by the authority of Plato, Descartes, and Kant; in religion by the authority of Christ, Paul, and Mohammed; in education and the State by the authority of most Governments; and in physiology by most of the older, and even some recent, physiologists. On this view, psychology is a special mental science, having only an external and limited connection with natural science. But modern comparative and genetic psychology, the anatomy and physiology of the brain, have, in the course of the last forty years, established the monistic view that psychology is a special branch of cerebral physiology, and that therefore all its parts and their application belong to this section of biology. The soul of man is a physiological function of the phronema. As I have fully explained the monistic conception of psychology in chapters vi.–xi. of the *Riddle*, and supported it with all

the arguments of anatomy, physiology, ontogeny, and phylogeny in my *Anthropogeny*, I need not go further into the subject.

The science of language shares the fate of its sister, psychology; by one section of its representatives it is taken monistically as a natural science, and by another section it is dualistically conceived as a branch of mental science. On the old metaphysical view, speech was regarded as an exclusive property of man, either a gift of the gods or an invention of social man. But in the course of the nineteenth century the monistic and physiological position that speech is a function of the organism, and has been gradually developed like all other functions, has been established. The comparative psychology of the higher animals showed that in various classes the thoughts, feelings, and desires of the gregarious animals are communicated partly by signs or touch, partly by sounds (the chirrup of the cricket, the cry of the frog, the whistle of many reptiles, song of birds and singing-apes, roaring of carnivora and ungulates, etc.). The ontogeny of speech showed that its gradual development in the child is (in accordance with the biogenetic law) a recapitulation of its phylogenetic process. Comparative philology taught that the languages of the different races have been formed polyphyletically, or independently of each other. The experimental physiology and pathology of the brain showed that a definite small region of the cortex (the Broca fissure) is the centre of speech, and that this central organ, in conjunction with other parts of the phronema and the larynx (the peripheral organ), produces articulate speech.

Historical science is, like philology or psychology, still conceived in different senses by experts. Very often

history is wrongly taken to mean the record of events that have occurred in the course of the development of civilised life—the history of peoples and States (humorously described as "the history of the world"), of civilisation, of morals, etc. This is merely an anthropocentric feeling that in the strictly scientific sense "history" can only be used for the record of man's doings. In this sense history is opposed to nature, the one dealing with the province of morally free phenomena (with pre-conceived aim), and the other comprising the province of natural law (without pre-conceived aim). As if there were no "natural history," or as if cosmogony, geology, ontogeny, and phylogeny were not historical sciences! Although this dualistic and anthropistic view still prevails in our universities, and State and Church protect the venerable tradition, there can be no doubt that sooner or later it will be replaced by a purely monistic philosophy of history. Modern anthropogeny shows us the intimate connection between the evolution of the human individual and that of the race; and by means of pre-historic and phylogenetic research it joins what is called the history of the world to the stem-history of the vertebrates.

Medicine belongs to the front rank of practical or applied sciences. In its long and interesting history it teaches how it is only a monistic knowledge of nature, not a dualistic notion of revelation, that affords the foundations of true science and the profitable application of this to the most important aspects of practical life. Medicine was originally the business of the priests, and for thousands of years it was under the influence of mystic and superstitious ideas which were connected

with religious dogmas. However, two thousand years ago the great physicians of classic antiquity made a serious effort to provide a solid base for medical practice by a thorough anatomic and physiological study of the human frame. But in the general reaction of the Middle Ages superstitious and miraculous ideas once more defeated independent scientific investigation. Disease was supposed to be the work of evil spirits (as Christ thought) which had to be exorcised. Miracles are still thought to take place, even in cultured circles. I need only mention the wonders of patent medicines, magnetic cures, Christian science, and other charlatanry. However, the great development of science in the nineteenth century, especially the astonishing advance of biology about the middle of the century, gradually shaped medicine into the monistic science which assuages so much pain and suffering in humanity to-day. Pathology, the science of disease, and therapeutics, the rational science of healing, are grounded now on the safe methods of physics and chemistry and a thorough knowledge of the human organism. Disease is no longer regarded as a special entity that comes on the body like an evil spirit or mysterious organism, but is conceived as a baneful disturbance of its normal activity. Pathology is only a branch of physiology; it studies the changes that take place in the tissues and cells under abnormal and dangerous conditions. When the causes of these changes are poisons or foreign organisms (such as bacteria or amœbæ), the art of healing has to remove them, and restore the normal equilibrium of the functions.

The science of mental disease is a special branch of medicine; it has the same relation to it as psychology has to physiology. However, as pathological psychology

it deserves special consideration, not only on account of its extreme practical importance, but also because of its theoretical interest. The misleading dualist idea of body and soul that has perverted our notions of mental life from the oldest times has led people to regard mental disorders as special phenomena, at one time directly as evil spirits that enter from without into the human body, at another time as mysterious dynamic occurrences affecting the mystic being of the soul (independently of the body). These dualistic and still widespread and mischievous errors have caused the most fatal mistakes in the treatment of mental disease; they have had the most unfortunate effect on juristic and social and other aspects of practical life. But the ground has been cut from under these irrational and superstitious ideas by modern psychiatry, which regards all mental disease as a disorder of the brain, and traces it to changes in the cortex that lie at the root of all psychoses (delusions, lunacy, etc.). As we call this central organ of mind the phronema, we may say: Psychiatry is the pathology and therapeutics of the phronema. In many disorders we have already succeeded in anatomically and chemically tracing the changes in the psychic or phronetal cells (the neurona in the phronema). These acquisitions of the pathological anatomy and physiology of the phronema have a great philosophic interest, because they throw a good deal of light on the monistic conception of psychic life. As the greater part (sixty to ninety per cent.) of these diseases are hereditary, and they have mostly been acquired gradually by the ancestors of the patient, they also afford clear proof of progressive heredity, or the inheritance of acquired characters.

Thousands of years ago, when barbaric races began to adapt themselves to civilised life, they had a concern

for their bodily health and strength. In classic antiquity, the care of the body by baths, gymnastic exercises, etc., was greatly developed, and connected with religious ceremonies. The splendid aqueducts and baths of Greece and Rome show how much importance they attached to the external and internal use of water. The Middle Ages brought reaction in this province like so many others. As Christianity depreciated this life and said it was merely a preparation for the life to come, it led to a disdain of culture and of nature; and as it regarded man's body only as the temporary prison of his immortal soul, it attached no importance to the care of it. The frightful plagues that swept away millions of men in the Middle Ages were only fought with prayer, processions, and other superstitious devices, instead of with rational hygienic and sanitary measures. We have only gradually learned to discard this superstition. It was not until the second half of the nineteenth century that a sound knowledge of the physiological functions and environment of the organism induced people once more to have a concern for bodily culture. All that modern hygiene now does for the public health, especially the improvement of the dwellings and food of the poorer classes, the prevention of disease by healthier habits, baths, athletics, etc., can be traced to the monistic teaching of reason, and is altogether opposed to the Christian belief in Providence and the dualism connected therewith. The maxim of modern hygiene is: God helps those who help themselves.

The remarkable progress of technical science in the nineteenth century, which has stamped our age as "an age of machinery," is a direct consequence of the immense advance of theoretical science. All the privileges and comforts which modern life gives us are

due to scientific discoveries, especially in physics and chemistry. We need only recall the enormous importance of steam and electric machinery, modern mining, agriculture, and so on. If by these means modern industry and international commerce have prospered beyond all expectations, we owe this to the practical application of empirical truths. "Mental science" and metaphysical speculation have had nothing to do with it. There is no need of further proof that all the technical sciences have a purely monistic character, like their exact sources, physics and chemistry.

The scientific development of education is one of the greatest tasks of modern civilisation. The ideas that are impressed on the mind in early youth are most persistent, and generally determine the direction of thought and conduct for the whole of life. Hence we find the struggle between the two philosophic tendencies assuming the greatest practical importance in this department. As the priests were, thousands of years ago, in the first stages of civilisation, the sole trainers of the growing mind, they had charge of the school as well as of medicine. Religion was made the chief foundation of instruction, and its doctrines were the moral guide for the whole of life. The isolated attempts that were made by monistic philosophy in ancient times to destroy this theistic superstition had no effect on the education of the young. In this the dualistic principles of Plato and Aristotle prevailed, their metaphysical theories being blended with the teaching of the Church. In the Middle Ages the power of the Roman priesthood enforced them everywhere. And, although a good deal of this teaching lost its prestige at the Reformation, the influence of the Church on the school was maintained down to our own time. The spiritual power of the Church finds a useful

ally in this in the conservative attitude of most Governments. Throne and altar support each other; both dread the advance of scientific inquiry. In face of this powerful dualistic alliance, supported by the mental apathy of the masses and a convenient blind submission to authority, the monistic system has a difficult position to maintain. It will only gain solid ground in education when the school is divorced from the Church and scientific knowledge is made the foundation of the curriculum. I have pointed out in the nineteenth chapter of the *Riddle* the guiding principles to be followed in this reform of education in opposition to the influence of Church and State.

As we have dealt in the eighteenth chapter with morals and their development from habit and adaptation, we need only mention here the contradiction that we still find between the monistic claims of pure reason and the dualistic claims of practical reason. This has been largely sustained by Kant's teaching, but his categorical imperative has been completely refuted by modern science. The metaphysical grounding of morality on free-will and ethical intuitions *(à priori)* must be replaced by a physiological ethic, based on monistic psychology. As this can no more recognise a moral order of the world in history than a loving Providence in the life of the individual, the monistic morality of the future must be reducible to the laws of biology, and especially of evolution.

The great importance that attaches to the new science of sociology is due to its close relations to theoretical anthropology and psychology on the one hand, and to practical politics and law on the other. When we take it in the wider sense, human sociology joins on to that of the nearest mammals. The family life, marriage,

and care of the young in the mammals, the formation of herds in the carnivora and ungulates and of troops in the social apes, lead on to the looser associations of savages and barbarians, and from these to the beginnings of civilisation. The history of these associations is connected with the social rules that govern the intercourse of smaller and larger communities. In the biological reduction of social rules to the natural laws of heredity and adaptation dynamic sociology (as Lester Ward has called it) proceeds on purely monistic lines, while in social intercourse itself we still find a good deal of dualism. How little truth and nature count for in our cultured society, how much hypocrisy and insincerity have to do with social rules, has been well shown by Max Nordau in his *Conventional Lies of Civilisation.*

Politics is closely connected with sociology on the one hand and law on the other. As internal politics it controls the organisation of the State by a constitution; as external or foreign politics it directs the relations of States to each other. In my opinion, pure reason should prevail in both departments; the relations of the citizens to each other and to the whole should be regulated by the same ethical principles that we recognise in personal intercourse. We are, unfortunately, very far from this ideal in the life of a modern State. Brutal egoism rules in foreign politics; every nation thinks only of its own advantage, and furthers it with all its military and other resources. Domestic politics is still largely directed by the barbaric prejudices of the Middle Ages. Great struggles are in progress between the central Government and the mass of the people. Both parties spend themselves in fruitless conflicts; yet reason in the life of the State suffers more than its special political complexion. "Whether the State shall be a monarchy

idealistic and pessimistic, whence Schopenhauer regarded it as the highest of all religions. On the other hand, belief in a personal God is the central feature of the three great Mediterranean religions. This anthropomorphic God is conceived in a hundred forms in the various sects of the Mosaic, Christian, and Mohammedan religions, but his existence remains one of the chief articles of faith. No evidence of his existence is to be found; this was very ably shown by Kant, although he thought that practical reason postulated it. All that revelation is supposed to teach us on the matter belongs to the region of fiction. The whole field of theology, especially dogmatic theology, and the whole of the Church teaching based on it, are based on dualistic metaphysics and superstitious traditions. It is no longer a serious subject of scientific treatment. On the other hand, comparative religion is a very important branch of theoretical theology. It deals with the origin, development, and significance of religion on the basis of modern anthropology, ethnology, psychology, and history. When we study without prejudice the results of these sciences bearing on religion, theology turns out to be pantheism, in the sense of Spinoza and Goethe, and thus Monism becomes a connecting link between religion and science.

This brief survey of the twenty chief branches of modern science and their relation to monism and dualism shows that we are still face to face with great contradictions, and that we are far from the harmonious and successful adjustment of these differences. They are partly due to a real antinomy of reason in the Kantist sense—an antithesis in ideas, in which the positive seems to be just as capable of proof as its contradictory. But, for the most part, this unfortunate antinomy in the sciences is connected with their historical development.

Pure reason, the highest quality of civilised man, was gradually evolved from the intelligence of the savage, and this in turn from the instincts of the apes and lower mammals; and many relics of its former lower condition remain to-day, and have, through practical reason, a most prejudicial influence on science. These dualistic prejudices and irrational dogmas—intellectual residua of the primitive condition of the race, fossil ideas and rudimentary instincts—still pervade the whole of modern theology, jurisprudence, politics, ethics, psychology, and anthropology. If we glance at the whole field of modern science at the beginning of the twentieth century in this connection, we can distribute its twenty sections into three groups—rational (purely monistic), semi-dogmatic (half-monistic), and dogmatic (predominantly dualistic) disciplines.

The following may be classed as rational or purely monistic sciences, in which no competent and thoroughly expert representative now admits dualistic considerations. Of the pure or theoretical sciences, physics, chemistry, mathematics, astronomy, and geology; of the applied or practical sciences, medicine, hygiene, and technology. On the other hand, in the semi-dogmatic sciences we still find a mixture of monistic and dualistic ideas in the appreciation of their aims and objects, one or the other prevailing according to the party position or personal training of the individual representative. This is the case with most of the biological sciences, biology (in the broadest sense), anthropology, psychology, philology, history, psychiatry; and of the applied sciences, pædagogics and ethics. The two latter sciences form a transition to the four purely dogmatic sciences in which the traditional dualism is still paramount: sociology, politics, jurisprudence, and theology. In these branches of

science medieval traditions retain a good deal of their power. Most of their official representatives cling to prejudices and superstitions of all sorts, and very slowly and gradually admit the acquisitions of pure reason as embodied in monistic anthropology and psychology. The intellectual life was in many respects more advanced at the beginning of the nineteenth than of the twentieth century.

This classification of the chief branches of knowledge in their relation to philosophy, the comprehensive science of general truths, is naturally only a provisional and personal sketch. It is especially difficult from the circumstance that all the sciences have very complex relations to each other, and have undergone many changes as to their aims and subjects in the course of their historical development. I will only point out that a good deal of science—in fact, the rational sciences with exact mathematical basis—have now been completely won over to monism; and in the semi-dogmatic sciences it is gaining ground from day to day, so that we may hope sooner or later to see the four dogmatic sciences also, the strong bulwarks of dualism—sociology, politics, jurisprudence, and theology—succumb to monism. For the ultimate aim of all the sciences can only be the unity of their underlying principles, or their harmonious unification by pure reason.

It is now more and more generally acknowledged in educated countries that a complete reform of our educational curriculum is needed, both in elementary and secondary schools and at the universities. The great struggle between two different tendencies assumes larger proportions every day. On the one hand, most Governments, following their conservative instinct, cling as far as possible to medieval traditions, and find support in

the dogmatic teaching of theology and jurisprudence. On the other hand, the representatives of pure reason seek to get rid of these fetters, and to introduce the empirical and critical methods of modern science and medicine into what are called the mental sciences. The opposition between the two parties is accentuated by their different sociological tendencies. Liberal humanists claim that the freedom and education of all men is the aim of progressive evolution, in the conviction that the free development of the personality of each individual is the surest guarantee of happiness. To conservative Governments this is a matter of indifference; they look on the individual citizens, in accordance with the manifold division of labour, merely as so many screws and wheels in the great organism of the State. The "upper ten thousand" naturally think of their own welfare first, and desire to keep all higher education to themselves. But in the light of pure reason the State is not an end in itself; it is a means to ensure the prosperity of the citizens. To each of these, whatever their condition, the opportunity should be afforded of acquiring the higher education and developing their talents. Hence in education we should impart a general outlook on all the sides of human life. Each should acquire the elements of science, not only of physics and chemistry, but also of biology and anthropology. On the other hand, the predominance of the classical training over modern ought to be restricted. Every student and every faculty should be occupied with only philosophy and science in the first sessions, and not take up special studies until afterwards.

At the close of the *Riddle* I brought out in clear relief the antagonism between modern monism and traditional dualism, but also pointed out that—

this strenuous opposition may be toned down to a certain degree on clear and logical reflection—may, indeed, be converted into a friendly harmony. In a thoroughly logical mind, applying the highest principles with equal force in the entire field of the cosmos—in both organic and inorganic nature—the antithetical positions of theism and pantheism, vitalism and mechanism, approach until they touch each other. Unfortunately, consecutive thought is a rare phenomenon in nature.

This conciliatory disposition has grown stronger and stronger in me. Every year increases my belief that the dualism of Kant and the prevalent metaphysical school must give way to the monism of Goethe and the rising pantheistic tendency. In this we do not lose sight of our ideals. On the contrary, our "realist philosophy of life" teaches us that they are rooted deep in human nature. While occupying ourselves with the ideal world in art and poetry, and cultivating the play of emotion, we persist, nevertheless, in thinking that the real world, the object of science, can be truly known only by experience and pure reason. Truth and poetry are then united in the perfect harmony of monism.

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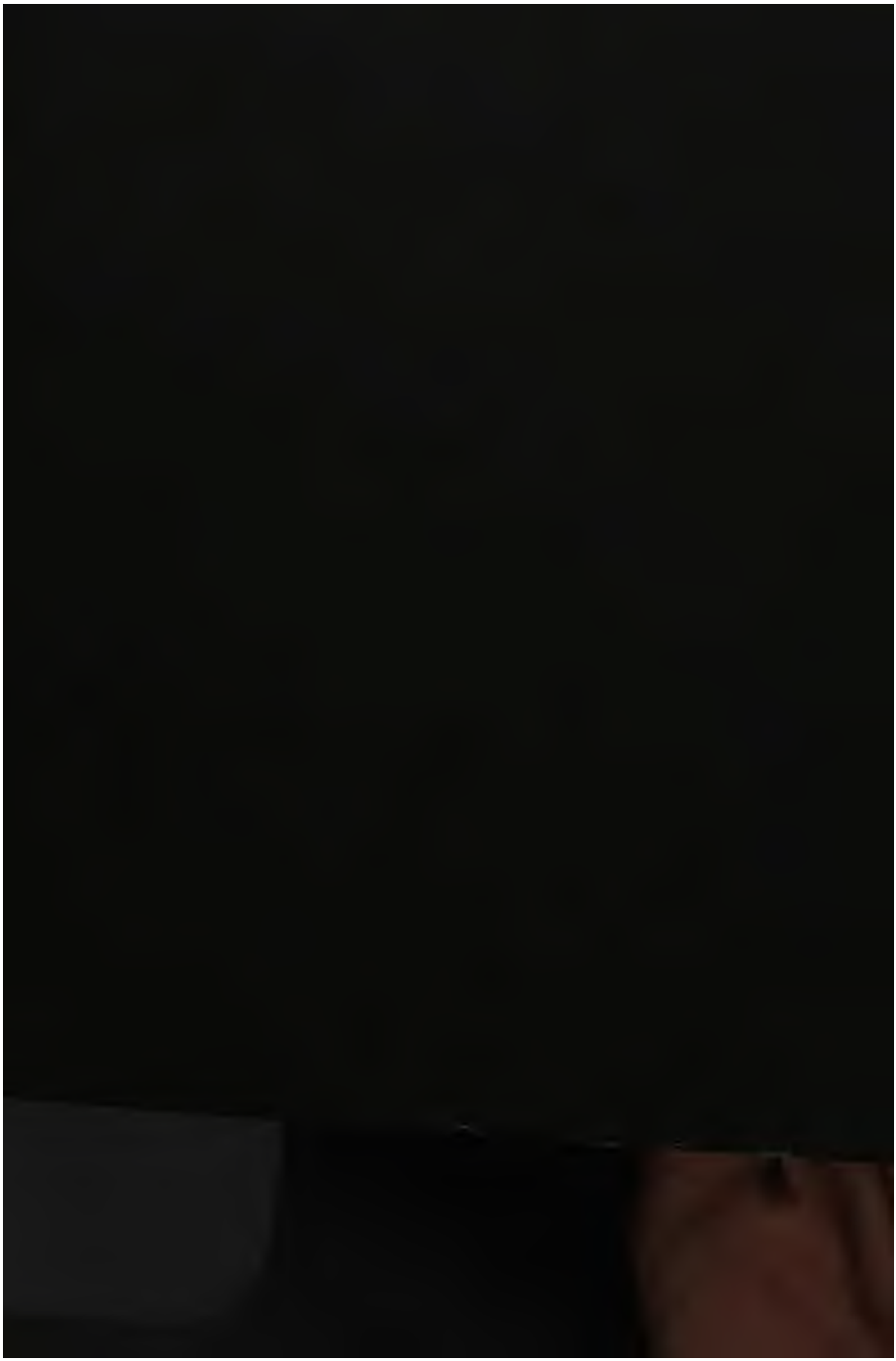
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MUTILATE CARD